The Children's Hour

WONDERS of SCIENCE

Selected & Arranged by
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Houghton Mifflin Company

Between the dark and the daylight, when the night is beginning to lower,
Comes a pause in the day's occupations, that is known as the Children's Hour.

NOTE

 The editor takes this opportunity to thank both authors and publishers for the ready generosity with which they have allowed her to include these stories in "The Children's Hour."

"The Cosmopolitan Magazine" ("The Wonderful New World ahead of Us," by Thomas A. Edison and Allan L. Benson); published by the International Magazine Company.

"Modern Industrial Progress," by Charles H. Cochrane; published by J. B. Lippincott Company.

"The World To-day" ("About the Pictures in Our Papers," by George D. Richards; "How We Know the Correct Time," by C. H. Claudy).

"McClure's Magazine" ("Making Moving Pictures," by Bennet Musson and Robert Grau; "Yellow Fever: A Problem Solved," by Samuel Hopkins Adams); published by The McClure Publications, Inc.

"The World's Work" ("The Farm-Boy Who Went Back," by H. Gard; "Doctor Succeeded Nevertheless,"

by W. W. Peter; "How Idaho got Pure Food," by Isaac Russell; "Doing Business by the Weather Map," by Allan P. Ames; "A Crater Full of Sulphur," by John M. Oskison; "About Nebulæ and the Spectroscope," by William Bayard Hale); published by Doubleday, Page & Company.

"The Fairy-Land of Science," by Arabella B. Buckley; published by D. Appleton & Company.

"St. Nicholas" ("The Story of the Fractions," by Grace Tabor; "The Magnet as a Useful Wizard," by George Ethelbert Walsh); published by The Century Company.

"The Story of the Plants," by Grant Allen; published by D. Appleton & Company.

"The Romance of Plant Life," by G. F. Scott Elliot; published by J. B. Lippincott Company.

"The Autocrat of the Breakfast-Table," by Oliver Wendell Holmes; published by Houghton Mifflin Company.

"Excursions," by Henry D. Thoreau; published by Houghton Mifflin Company.

"Recreations in Botany," by Caroline A. Creevey; published by Harper & Brothers.

"Talks Afield," by L. H. Bailey, Jr.; published by Houghton Mifflin Company.

"Through Magic Glasses," by Arabella B. Buckley; published by D. Appleton & Company.

"Everybody's Magazine" ("Making Four-leaved Clovers," by Eugene P. Lyle, Jr.; "Celestial Photography," by Huber William Hurt); published by Ridgway Company.

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"Walks and Talks in the Geological Field," by Alexander Winchell; published by Scott, Foresman & Company.

"The Story of the Bacteria," by T. Mitchell Prudden; published by G. P. Putnam's Sons.

"Our Friends and Foes of the Invisible World," by Harvey Hersey; published by the Neale Publishing Company.

"The Boy's Book of Inventions," by Ray Stannard Baker; published by Doubleday, Page & Company.

"America at Work," by Joseph Husband; published by Houghton Mifflin Company.

"The Great Ball on which we Live," by Charles R. Gibson; published by J. B. Lippincott Company.

"The Boy's Second Book of Inventions," by Ray Stannard Baker; published by Doubleday, Page & Company.

"A First Book in Geology," by N. S. Shaler; published by D. C. Heath & Company.

"Town Geology," by Charles Kingsley; published by D. Appleton & Company.

"Popular Science Monthly" ("Why the Slides slide at Panama," by J. F. Springer); published by the Modern Publishing Company.

"The History of a Mountain," by Élisée Reclus; published by Harper & Brothers.

"Travels in Alaska," by John Muir; published by Houghton Mifflin Company.

"The Mountains of California," by John Muir; published by The Century Company.

NOTE

"The Earth's Beginning," by Sir Robert Stawell Ball; published by D. Appleton & Company.

"Mont Pelée and the Tragedy of Martinique," by Angelo Heilprin; published by J. B. Lippincott Company.

"Extinct Monsters and Creatures of Other Days," by H. N. Hutchinson; published by D. Appleton & Company.

"Sparks from a Geologist's Hammer," by Alexander Winchell; published by Scott, Foresman & Company.

"Astronomy with an Opera-Glass," by Garrett P. Serviss; published by D. Appleton & Company.

"Home Progress" ("Shooting Stars," by Elizabeth G. Chapin); published by Houghton Mifflin Company.

"The Outlook" ("The Greatest Camera in the World," by Edward Arthur Fath); published by The Outlook Company.

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TO THE CHILDREN

EVERYBODY likes something new. The moving-picture people say that they are always on the lookout for plays that are original, that bring in unexpected events and unheard-of adventures. If you open a new story book, you like it to be fresh and unusual in plot and incident. If you are roaming about a strange city, you like to go a little farther on, just to see what is around the next corner. If you are among the mountains, you want to know what is on the other side of the one that shuts off the distant view. If you are on the ocean, you are interested in every little change in sky and water.

You cannot always have a new and original book, or visit strange cities or lofty mountains, or take an ocean voyage, but you can always find something in science that you did not know before, even if you have only the simplest instruments. In astronomy, for instance, what you can see with just your own eyes is not to be scorned, — provided you think as well as look, — and with an opera glass you can get considerable knowledge of the skies. You can see the moons of Jupiter, the separate stars of the Pleiades, the mountains of the moon, and, with a bit of smoked glass, the spots on the sun. So in geology. Examine the stones in an old wall. Notice that some are made in strata, while others look as if they were well stirred up before cooling. Some are

fine-grained, others are coarse. Look a little more closely, and you may find some tiny clear crystals or red garnets or perhaps a fossil or two. Look at the nearest railroad cut and imagine the old sea beach that used to be there, first, perhaps, covered with fine sand, then, after a storm, with pebbles and pieces of broken rock. If no stone wall or railroad cut is near, examine the stone foundations of the houses, or even the bricks or stones of the pavement.

Botany is the most convenient of studies, because there is always material at hand. If it is only a geranium in a flowerpot, notice the shape and indentations of the leaves. Are the stamens all alike and of the same length? Why do the evening primrose and the nicotiana open at twilight and the morning-glory at sunrise? What is the shape of the stem of mint? Why are the stems of the grasses hollow? What happens if you lift a stamen of laurel from the little pocket in the petal where it rests? What happens if you touch the base of a barberry stamen with a pin? Why do bell-flowers, like lilies-of-the-valley and Canterbury bells, droop their heads, while daisies look straight up to the sun?

In the study of chemistry and electricity there is a new "wonder" for every moment! And in matters nearer home, the "doctoring" of trees, farming, cooking, the care of roads and sidewalks, the prevention of the white blotches that form on brick buildings — if you look into any one of these for ten minutes, you will find something new and interesting. Moreover, in every branch of knowledge there is room for discoveries. Alexander Graham Bell says, "Great dis-

coveries and inventions have originated from very little things." First of all, however, any one who hopes to become an inventor, or even to find something new in whatever comes before his eyes, must follow Dr. Bell's advice and take to heart what he calls "the importance of observing closely every little thing you come across and of reasoning upon it."

WONDERS OF SCIENCE

THE WONDERFUL NEW WORLD AHEAD OF US

By Thomas A. Edison

(Reported by Allan L. Benson)

ON my way over to the laboratory, I had mapped out in my mind a list of questions that I wished to ask. Edison did not wait to see the map. He knew what he wanted to discuss first. What he wanted to discuss first was money, not silver, not bank-notes, not government certificates—gold. He believes gold will not much longer lure; that it may be left out at night as safely as iron may be left out at night; that nobody who works will accept gold in payment for his work; and that no nation will issue gold as money. He holds these views because he believes it is only a question of time until a way will be discovered to manufacture gold.

"The discovery may be made to-morrow," he said. "It is just as likely to be made to-morrow as at any other time. The discovery will surely be made some time, because the making of gold is a question only of the proper combination and treatment of matter. I mean by this that all matter is alike. Silver and gold differ only because the matter in them was combined in different proportions and treated in a different manner. Who knows but radium has the power to convert a cheap metal into a dear one? If not radium, something else."

The contemplation of the possibility held him silent for a moment.

"Radium is a wonderful metal," he continued. "We know next to nothing about it. The fact of its discovery was made known to us one morning in the newspapers. News of the discovery of some metal even more wonderful may come to us in the newspapers to-morrow morning. All over the world, scientists are working hard to try to find out the secrets of things. Every fact we find makes it easier to find the next fact. Nothing that is reasonable is impossible, and it is reasonable to expect that we shall find out how to make gold."

Edison said he had often noted the gold clause in contracts, whereby the debtor agrees to pay his debt "in gold coin of the United States, of standard weight and fineness." The clause always seemed to him to be dangerous. The ownership of most of the property in the world might at any moment be transferred from the creditor to the debtor class. He shook his head and smiled.

"Oh, that gold business," he said, "does not strike me as right. It is funny that the world still clings to it. What a snap it would be for the railroads, for instance, if they could pay their bonds with gold that they made at a cost of not more than twenty-five dollars a ton. They may do it, some day."

Edison ought to know a good deal about transportation, so I asked him what improvements were probable in the means of transportation. Would electricity always be used only for short hauls? Was nothing better than steam in sight for long hauls? Should we always

travel by steam to Chicago, to Denver, to San Francisco? Should we never travel by air?

Edison answered the aeroplane question first. He answered it by telling a story. Ten years ago he was sitting in front of his winter laboratory in Florida. Not a cloud was in the sky. The air, bathed in sunshine, was still. The smoke from a neighboring chimney went straight up — straight up for a thousand feet. Almost as high as the pillar of smoke soared a buzzard. Minute after minute, as Edison watched, the bird lazily described great circles. Sometimes it would slide down the air a hundred feet and then climb back again. But whether the bird circled, slid, or climbed, it never flapped a wing. Always its wings were like the hands of a clock at a quarter to three.

Edison marveled. With no wind blowing, no wing flapping, what kept the bird aloft? What enabled it to climb after it had slid down the air? Again and again, he asked himself these questions, but the answers did not come. Nine years later, the answers came.

"I think I know what kept that bird in the air," he said to me. "It traveled on sound-waves, and the little pin-feathers on the insides of its wings made the waves."

What he meant was this: Any agitation of the air makes a wave. Agitate the air rapidly enough and the waves come to us in the form of sound. Then the waves are called sound-waves.

"The air, when struck with sufficient quickness," continued Edison, "is as rigid as steel. Touch a match to a stick of dynamite on a five-ton rock and nothing will happen — the dynamite will merely burn up. Set off

a charge of gunpowder and the dynamite will be exploded, but not rapidly enough to shatter the rock. But explode the dynamite with a fulminate of mercury cap and the explosion will come so quickly that the air cannot yield. The rock will be split, because it is less rigid than the air."

Edison believes the buzzard kept aloft by causing the pin-feathers on the insides of its wings to beat the air with tremendous rapidity. He believes the buzzard traveled on sound-waves, precisely as the bumblebee travels on sound-waves. The bumblebee derives its name from the fact that, in flying, it makes sound-waves.

Edison has a high regard for the bumblebee as a flier. He says its wings are exceedingly small in proportion to the size and weight of its body. It flies so well only because it uses its wings so well; beats the air until the air becomes like metal stilts. Moreover, he believes we shall have to learn wisdom from the bumblebee before we shall travel in the air very far, very fast, or very safely. He would apply the bumblebee principle to lifting the flying-machine, and the present propeller system to driving it ahead. In his opinion, flying-machines should be able to go straight up. Aeroplanes can go up only as they go ahead. "Suppose you had four million trained bumblebees," he said, "attached to wire wickerwork on which was seated a man. Can't you understand that if the bumblebees were signaled to fly, they would lift the man? I believe mechanical bumblebees could be so attached to a flying-machine that they would lift it straight up. By 'mechanical bumblebees' I mean in-

clined planes revolving upon perpendicular shafts at tremendous speed. Once in the air, ordinary propellers could be used to drive the machine ahead."

Edison believes that the present type of aeroplanes will soon be discarded, and that "bumblebee fliers" will carry passengers at the rate of a hundred miles an hour, or more.

Meanwhile, transportation upon land, he declares, will be revolutionized. The steam locomotive is blowing its last blasts for millions of people. The next generation of New Yorkers and New Englanders will first hear at school of steam locomotives, and never will see them unless they go to some State that has neither much water-power nor much population. Water-wheels will make electricity to run all the railroads that traverse regions in which there is abundant water-power. Whole systems like the Great Northern will be thus operated. In densely populated States, electric locomotives will displace steam, regardless of whether water-power is available. The New York Central will be electrified from end to end. Nor will there be, says Edison, in all New England or New York, a railroad operated by steam power.

Yet the changes Edison foresees in the methods of transportation are less radical than the changes he foresees in the use of iron and steel. Steel, he says, is destined soon to fall from its high pinnacle as the skeleton of sky-scrapers, to become the material of which furniture is made. Book covers may also be made of steel. Even the pages of books may be made of steel, though Edison regards nickel as a better substitute for paper.

Here, indeed, is a case where the small end of a subject is the big end. The imagination is not much taxed by the suggestion of sky-scrapers made without steel; but nickel books, bound in steel —

"Why not?" asked Edison. "Nickel will absorb printer's ink. A sheet of nickel one twenty-thousandth of an inch thick is cheaper, tougher, and more flexible than an ordinary sheet of book-paper. A nickel book, two inches thick, would contain forty thousand pages. Such a book would weigh only a pound. I can make a pound of nickel sheets for a dollar and a quarter."

Here, at last, is comfort for the librarians who are crying out against the commercialism that produces paper so poor that most of the volumes printed to-day seem likely to crumble to dust within a hundred years. Here, also, is a prospect of real culture for the masses. Forty thousand pages in a volume! A single volume the equivalent in printing space of two hundred paper-leaved books of two hundred pages each! What a library might be placed between two steel covers and sold for, perhaps, two dollars! History, science, fiction, poetry — everything. Indestructible except through fire or abuse. Beautiful, because the steel covers could be stained in perfect imitation of the finest leathers. Two hundred books for the price of one book!

I had understood Edison to say that he was already making, for another purpose, the thin nickel sheets of which he spoke. That seemed to make the nickel book close within the range of present possibilities. Then it occurred to me that perhaps he had mastered only the problem of manufacturing in small lots. So I said: —

"Suppose you were to receive from a publisher an order for a sheet of nickel seven feet wide and a thousand feet long — could you fill it?"

"I could fill an order for a sheet of nickel seven feet wide and *a mile long*," he replied.

Then he told how he makes nickel sheets so thin. It is entirely an electrical process, accurate to a high degree. An electric current in operation for half a minute deposits on a prepared base one twenty-thousandth of an inch of nickel; never more, never less.

"An absolute law governs this," said Edison.

An absolute law appears to be operating to substitute steel for wood in the making of furniture. The law is the increasing cost of wood. Edison says one New York firm is already making steel office-furniture. No tubing is used. The various parts of chairs, tables, and desks are stamped out of steel sheet, and then bent into shape. The legs, arms, and backs of chairs are cut out as rapidly as the big wheels of stamping-machines can revolve.

"All furniture will soon be made of steel," said Edison. "The steel required for a given piece of furniture costs only one fifth as much as the wood would cost for the same piece of furniture. Steel furniture is light, because only a little steel is required. And polished steel takes a beautiful finish. It can be stained in perfect imitation of mahogany, walnut, cherry, maple, oak, or any other wood. The babies of the next generation will sit in steel high-chairs and eat from steel tables. They will not know what wooden furniture is."

Nor will these children, according to Edison, ever see

the huge steel bones of a sky-scraper swung into place. He says the "age of steel," about which we brag so much, is nothing to brag about. We brag about it because we do not know any better. Steel costs too much. It was a mistake to use it in the first place. The ancient Egyptians are held responsible, in a way, by Edison, for our mistake. Ancient Egyptian builders used sun-dried bricks. The sun was too slow for us, and we built fires to dry our bricks. But we clung to bricks — bricks and stones.

"Men are lunatics," declared Edison, "to keep on building with brick and steel. Reinforced concrete is better and cheaper than either. Builders who stick to brick and steel are behind the times. Men who put up wooden structures are worse lunatics. It is because we use such building materials that the fire losses in this country amount to almost $500,000,000 a year. Think what a waste of materials and labor this sum represents. It is all unnecessary. Reinforced concrete is not only cheaper than brick and steel, but it is fireproof. A reinforced concrete building will stand practically forever. Within thirty years, all construction will be of reinforced concrete, from the finest mansions to the tallest sky-scrapers."

I asked him if he could reproduce the fifty-story Metropolitan Tower in concrete.

"Certainly," he replied. "There is a fourteen-story concrete building in Brooklyn and another in Cincinnati. An earthquake could n't overturn them. What building material could be stronger than a solid mass of concrete tied together with steel?"

I could n't tell him. All I could do was to switch the forecasting from the housing of men to the transmission of thought. Edison had a good deal to do with the bringing out of the telephone. Perhaps he could conceive of something better than the telephone; better than the telegraph; better even than the Marconi wireless — something that would utilize a new force of which mankind is not yet conscious.

He could conceive of such a force. "So far as I know," said he, "there is no quality of the ether that will permit us to send wave-impulses in other than the electrical form, but I have no doubt that wave-impulses can be sent in other and perhaps better forms. I do know, however, that the present telephone is very imperfect. If you want to know how imperfect it is, read the drug market to a stenographer at the other end of the wire and see how much of it she will get. The success of the telephone is due to human imagination. A man is rung up on the 'phone. He gets a clue to the identity of the person who is calling him, and, if the subject broached is one with which he is familiar, the rest is easy. But mention a name that the other man did not expect to hear, and see how quickly he will break in with 'What's that?' 'Repeat that name,' and, finally, 'Spell it.'"

Edison told a story to show that even a good imagination is a poor substitute for a good telephone or a good telegraph wire. The anecdote related to the time when he was a telegraph operator in Louisville. His business was to receive and copy press dispatches. The people roundabout read the dispatches in the morning newspapers and believed they were reading reports sent by

telegraph. They were not. The news comes late, but it comes from Edison. Edison confessed to me that he "made up" at least seventy per cent of the material of each dispatch. Only thirty per cent actually came over the wire. He had to make up the other seventy per cent. The wire always worked badly, and he was on the "blind side" of a repeater where he could n't ask the sending operator to repeat.

"I never was caught but once," said Edison. "Please notice that I said 'caught.' I made plenty of minor mistakes. But once I was caught. I had been working on the wire three months, I guess, and getting along very well. Then, as now, I had a good memory, and, in order to keep in touch with the news matter I was handling, I used to take an armful of exchanges home with me each night, pile them on my bed and read them, sometimes until two o'clock in the morning. In this way I kept pretty good track of what was going on in the country.

"Down in Virginia the Legislature was trying to elect a United States Senator. John M. Botts was the leading candidate. But he never received quite enough votes to elect him. Day after day, the sessions dragged along. One day the news came that the opposition to Botts was going to pieces and that he would undoubtedly be elected the next day. The next day, just as a dispatch from Richmond began to come, the wire 'broke.' The wire broke just as I had received the name, 'John M. Botts.' I took a chance and wrote out a dispatch to the effect that Botts had been elected. The Louisville papers printed it. The following day they printed a correction.

Botts had n't been elected. The Legislature, as usual, had only adjourned for the day."

Edison believes the day will come when the telephone will leave little or nothing to the imagination; when it will shout out proper names, or whisper the quotations from the drug market. He depends upon Mr. Vail, the head of the American Telegraph and Telephone Company and of the Western Union, to bring this day quickly.

"Mr. Vail is a big man and a very smart business man," said Edison. "Until his day, the telegraph business was in the hands of little men. Vail will encourage inventions. He is something of an inventor himself."

If Mr. Vail has as hard a time improving the telephone as Edison had improving the phonograph, he will be quite busy for two years after he begins. Edison's first phonograph could n't say "sugar." The cylinder failed to deliver the "sh" sound. A phonograph that could n't say "sugar" being somewhat akin to a hare-lipped man, Edison undertook to remedy the defect. He did everything he could think of, but everything he could think of did no good. After he had toiled at the task eighteen hours a day for two years, he did something that he did n't think of that did good. To this day, he does not know what he did. All he knows is that his phonograph suddenly barked out "sugar" without a letter missing. Unconsciously he had remedied the defect that he could not remedy consciously.

"Do you know," he said, "I believe men do lots of things unconsciously. Sometimes these things help them, as the thing I did to the phonograph helped me;

sometimes they bother them, as an ore experiment once bothered me. I was trying to reduce iron ore by a new process. I selected some ore for a test. The test showed twenty per cent iron. The regular run of the mill showed only sixteen per cent. Again and again I selected samples, and the tests continued to show twenty per cent. As persistently, the mill refused to give anybody else more than sixteen per cent. Finally, I shut my eyes when I picked out pieces of ore to test, and then I got sixteen per cent the same as the others. Unconsciously, you see, I had been picking out better samples than I should have taken. A lot of subconscious business was working in spite of me."

Thus does the machinery of Edison's brain sometimes play him tricks. Edison calls the brain a "meat machine" — a machine made of "meat." He says the next generation will see metal machinery that, in wonderfulness of performance, will almost rival the brain itself.

Cloth, buttons, thread, tissue paper, and pasteboard will be fed into one end of a machine, and suits of clothing, packed in boxes, will come out at the other. Bound books will fall from the press. The machine that takes in lumber will give out finished furniture. In other words, machinery will make the parts of things and put them together, instead of merely making the parts of things for human hands to put together.

"Invention is in its infancy," said Edison. "Infants have to creep before they can walk. Inventors had to begin by inventing machinery to make only the parts of things. They have made great progress in this line. But the time has now come to take the next step and invent

machinery that will not only make the parts, but put the parts together. It is all a matter of brain-power on the part of the inventor, and the world is already developing such brain-power. Look at the Jacquard loom. What a wonderful principle it embodies. Cards with holes punched in them control twenty or thirty shuttles. Adjust those cards in a certain way and the Lord's Prayer will be woven in silk. Adjust them in another way and Roosevelt's portrait will be woven.

"I expect to see the Jacquard card principle applied to many kinds of machinery. So far as I can see, there is almost no limit to the extent to which it may be applied. There is no doubt that a machine could be made on this principle that would take the raw materials at one end and turn out finished suits of clothing at the other, wrapped, boxed, and ready for shipping. Moreover, such a machine will soon be here. The day of the seamstress, wearily running her seam, is almost ended. There is no reason why women should be made to do what machinery can do better. Human labor is slow and expensive, even when it is applied to machinery in making the parts of things, or in putting the parts together. Machine labor is cheap because its product is so enormous in quantity. Many years will not pass before machinery will make clothing so cheap that any one can afford to have four or five suits of clothes a year. Men's shirts will be made at a single operation by machinery, women's coats, shirt-waists, and skirts — oh, everything, I guess, but hats."

Edison is confident that a great shake-up is destined to take place among the farmers. He says the farmers

need to be shaken up; that they are "shy of brains"; that most of the brainy farmer boys go to the cities, notwithstanding that nowhere else are brains more needed than on the farm.

Edison believes the present type of farmer and the present methods of farming are destined to disappear; that in place of the present farmer will come a shrewd business man who will be at once a soil chemist, a botanist, and an economist; that in place of the present farmer's machinery will come implements in comparison with which the best agricultural implements now known will seem primitive; that storage batteries will drive ploughs that will make a dozen furrows each time they cross a field, and harrows that will mellow the earth more rapidly than ever horses could mellow it — in fact, that storage batteries will furnish most of the power needed on a farm.

"I think the coming farmer," said Edison, "will be a man on a seat beside a push-button and some levers. The present trend all points to this conclusion. We are making wonderful headway. Twenty years ago, we knew almost nothing about scientific agriculture. Now we are beginning to get an inkling of the causes that lie back of land deterioration. We are also learning something about the methods of restoring soil fertility. Simultaneously, invention has brought about great improvements in farm machinery. Gang-ploughs are now pulled by gas engines, and wheat is cut and bound by machinery. It is hard to keep up with the latest thing out in the line of farm implements.

"The railroads and the Government are largely re-

sponsible for farm progress. They dig out facts in their laboratories and at their experiment stations, then send men into the country, not only to tell the farmer the facts, but to show him how to use them. But we shall make infinitely greater progress, both in the science of agriculture and in agricultural methods. Farming, I believe, is destined to evolve into a great business proposition, conducted by sharp business men."

What a flashlight picture of the future! Man, at last, coming into his own. Coming into his own because he knows how to use his own. Knows how to use his own because he knows what is his own. Knows what is his own because his own brain, that has developed so slowly, has told him. Has told him that everything on earth, in the sky, and beyond the sky are his own. That the lightning can be bended to his will, the cataract harnessed to his need, and the dead iron in rocks fashioned into tongues that speak and hands that make. Hands such as never were human hands. Hands that can spin a thread of silk or crush a ton of rock. Hands that can make in abundance whatever human beings need.

What a flashlight of the future!

THE AGE OF PAPER

(*Abridged*)

By Charles H. Cochrane

THERE is no more common article of manufacture than paper, and there is scarcely a trade or business that is not dependent upon its use. Without cheap paper half of the business of the country would be paralyzed. It is because paper is so cheaply produced and so easily obtained that we seldom think of its value in all lines of industry.

In 1794 the first paper mill of the United States was started in Troy, New York, having a capacity of five to ten reams a day of rag pulp. Several other paper mills were started during the following years, manufacturing rag pulp by hand until 1817, when the first steam mill was started at Pittsburgh. By 1842 there were some fifty thousand persons employed in the paper-mill industry in the country, producing paper annually of the value of fifteen million dollars.

Pulp straw made its appearance in 1857, being manufactured at Fort Edward, New York. By the time the Civil War broke out, newspapers were using this straw-paper very largely, the price of rye straw increasing from six to twenty dollars a ton. Poor and brittle as this paper was and hard on printer's type, yet the newspapers were glad to get it at from twelve to twenty-six cents a pound during the war. Newspaper circulations were

largely stimulated by the political excitement culminating in 1861, and as a result the product of our paper mills began to exceed that of Great Britain and France. A boom in paper-making came with the introduction of wood paper about 1870–75. At first wood paper was regarded as a cheap article comparable with straw-paper; but, as its merits were better understood and as the makers learned improved ways of strengthening and finishing, its popularity began to grow, and to-day ninety-nine hundredths of the world's paper made is of wood, fine papers designed for the higher grade of artistic printing being manufactured from wood pulp and depending upon sizing and calendering for their beauty.

Cellulose is the chemist's term for the substance obtained by pulping wood, as in the manufacture of paper. Wood pulp is the common term used in the paper trade, meaning what its form implies — wood that has been reduced to a pulp. Most of the wood used in the manufacture of American papers grows in the forests of Canada and of the northern borders of the United States.

The hardy lumbermen chop down the trees and lop off the branches, leaving the trunks to lie until the logging season sets in. The transportation of the logs to market involves great ingenuity because of their size and weight, and the fact that they are obtained in sections where there are no good roads or ordinary methods of transportation.

Advantage is taken of the natural slopes toward the streams to form chutes down which the logs readily descend during wet or icy weather by force of gravity.

Very rude railways are also employed at times or any special device that the locality and ingenuity of the man in charge can suggest. When the logs reach the streams during the cold weather, they must lie there until the ice breaks up, and then the lumbermen prepare to go on the "drive." Logs are constantly forming jams in the streams, and when one of these occurs it becomes the difficult task of the lumbermen to walk over the floating logs and find the log that serves as a key to the jam, cutting it away so as to break the jam. The instant the jam begins to yield is the dangerous one for the lumberman, as he must run over the tops of the logs for shore in a race for his life. If he falls between the logs at such a time, when the pent-up force of the stream is bringing down thousands of heavy logs past the point of stoppage, he is sure to be crushed like an egg-shell, and usually his companions never even discover his remains.

The dangers of logging seem to give it an added charm in the eyes of the lumbermen, who acquire astonishing skill in balancing, and appear as much at home on a stream full of logs as a dancing-master is on a ballroom floor. These hardy men keep their logs in motion until they reach a large sheet of water, where they can be tied in rafts and floated to the mills. If the logs have been cut in a maritime province of Canada, they have yet a sea voyage before reaching the paper mill, or, if in the lake region, a similar trip across the waters of one of the Great Lakes is required to bring them to their destination. For such voyages the logs are made up in great rafts for towing. The sea or lake voyage is uneventful enough in fine weather, but a storm is liable to

break up the raft and scatter the logs for miles, with no little danger to the sailing craft in the vicinity, as a collision with a big log is damaging to the side of any vessel.

Paper mills are invariably located in the vicinity of water, as near some large waterfall as practicable. The waterfall is necessary for procuring cheap motive power, as well as a plentiful supply of water, which is essential to the manufacture of paper. When the log reaches the mill it is first dragged out of the water by iron "dogs" and rolled and slid to a great circular saw that cuts it into lengths. At the same time, a "barker," made of rapidly rotating blades, removes the bark from the log with the most tremendous noise. The buzz-saw is supposed to emit one of the worst noises that ever afflicted human ears, but the barker can outscreech three large buzz-saws, and when several saws and barkers are operating together, the noise is so deafening as to be beyond the writer's powers of description.

The short lengths of logs when bared of bark are ready for the grinders. In these the wood is pressed hard against a grindstone under a constant flow of water. The ground pulp is called "filler," which constitutes about seventy-five per cent of the material used in paper-making. The grinding of the wood tends to destroy the fiber, and for that reason in manufacturing the better grades of wood paper a chemical process is employed, commonly known as the "sulphite process." For this the logs are reduced to chips by a machine having rotating knives, and called the "chipper." This reduces the log at a rapid rate, and the stream of chips is

transported by an endless carrier to the sulphite mill to be digested. The digester is an enormous steel tank or boiler, lined with tile or the like to prevent the acid from eating into the steel sides. Some of these digesters are large enough to hold forty cords of chips at a single loading. Into the top the chips are dumped, after which the top is closed and the steam turned on, and the whole cooked at a temperature of perhaps 400° Fahrenheit for about eight or ten hours. The digested material is taken out through a manhole at the bottom of the digester, and strained to remove any coarse particles of foreign matter, then pressed to exclude surplus water, after which it is ready for the paper mill. The material obtained by this sulphite process being made from the chips retains longer fibers when reduced to pulp than does that which is ground, and it is this fiber which, entering into the finished article, gives added strength to the paper.

Next the pulp is pumped up to the "wet end" of the machine. Paper-makers call one end of the long paper-making machine the "wet end" and the other the "dry end." First at the "wet end" is the screen, a boxlike arrangement where the pulp is screened of all slivers and particles too large to knit into the paper fiber. From the screen it flows into the head box, which is a contrivance that automatically governs the head or flow of pulp upon the machine. This flow has to be nicely adjusted. The flow must be just right for the sheet of paper to be of the right thickness. From the head box the pulp flows out with the wood fiber held in such thin solution that it looks like very thin milk.

In one form of machine the pulp flows on to an endless wire straining-cloth that permits the running off of a large portion of the water. This cloth is guarded on the sides by endless bands or deckles that run under the "dandy-rolls" of the machine. These rolls carry the wire cloth, and any particular pattern of wire will produce a corresponding watermark. The arrangement of the wires at the dandy-roll also serves to determine whether the paper is "laid" or "wove." While the film of pulp is traveling to the apron, it is subjected to a side-shaking in order to cause the fibers of the pulp to cross each other.

After passing the dandy-roll, a save-all box catches and preserves the water that drains off, in order to save any size or coloring-matter that it contains. The film of pulp passes on to the "couch-rolls," and thence to an endless wet felt apron, on which it rests while carried between a pair of rolls, by which it is transferred to the press-felt apron, and passes to the pressure rolls. These rolls press out nearly all the remaining water and bring the pulp film almost to the condition of paper. From this point, the paper, as it may now be called, is able to carry itself without a blanket support, and is directed on between various drying and calendering rolls, some of which are heated in order to take out any remaining dampness from the paper. As it emerges from the machine, the paper is wound up in enormous rolls, often a mile or more in length.

About twenty million pounds of paper a day are manufactured in the United States, this being greater than the total output of the mills in all other parts of the

world. A little more than a quarter of this goes into the newspapers of the country, a little more than one eighth into books and magazines, and about one twentieth part into writing-papers. The remainder is made into wrapping-papers and paper boards, for boxes and similar purposes.

In 1891 the "Philadelphia Record" made a test as to the speed with which a tree in the forest could be converted into a newspaper ready for sale. The concern owned a paper mill, and so was able to carry out the experiment satisfactorily. The time from the putting of the axe to the tree to the offering of the newspaper on the street was twenty-two hours. There are several Sunday newspapers in the United States that consume as much as a hundred tons of paper in printing a single issue, thus consuming about one hundred and twenty-five cords of wood and clearing off about six acres of well-grown spruce timberland.

Japanese paper is a distinctly different product from American-made paper. It has a strength of fiber unknown here, and is superior in many ways, as well as much more costly, being hand-made. They use the bark of plants, as the kodzu, cutting it into strips of perhaps a yard in length, which are tied up in bundles, and then softened in water containing a weak solution of lye. The next process is treatment with a special form of mallet for separating the strips into fine fibers, and this is done with a care that secures a much longer fiber than is had in American manufacture. In making paper they use instead of the animal glue, which has such a rank odor, a cement made from the roots of a native plant. The

pulped fibers are spread on a sieve to level out the mass by shaking and to let the water drain off, much as we do in making paper by hand, after which it is rubbed on a board with a soft instrument, and dried in the sun, when it peels off the board as a sheet of remarkably tough paper. It is this sort of paper that the Japanese use for window-glass, and it is also twisted into threads of great strength that are used in embroidery and ornamentation. This paper is also specially adapted by its porous quality to use for writing on with India ink and a brush, and also for native painting.

ABOUT THE PICTURES IN OUR PAPERS

By George D. Richards

WHEN you pick up your morning paper, the first thing that meets the eye, after the headlines, is the first-page cartoon. With every important piece of news there is a large portrait, or a group of foreign views, or a war map. If there has been a crime or an accident, there are photographs or sketches of all the details and persons concerned. Along with not a little rubbish, these profuse illustrations of the modern newspaper contain much that is valuable and helpful in the understanding of the day's events.

Little is known outside of the newspaper office of the sources from which the pictures to illustrate news are gathered. Every one understands in a general way the numerous channels of news supply, but it is a mystery to many people how a man's picture appears with the announcement of his sudden prominence, or how a fire or tornado in some small town is often illustrated with the first appearance of the news. The system that makes such things possible in a daily newspaper is the growth of about thirty years. The first illustrated daily to live for any length of time was the "New York Graphic," started in 1873. This was not a great success, and it was seventeen years before a second venture was made with the "Daily Graphic" of London, which has contin-

ued to live and is still without a rival in its own sphere. The first colored supplement was brought out at Christmas, 1891, by the "New York Herald." The notable progress made in the last fifteen years is due almost entirely to photography and half-tone engraving, a process which has replaced the old woodcut by mechanical reproductions of photographs, paintings, and drawings.

The system for the distribution of news has developed so rapidly during the past two decades that it almost annihilates time and space. News is now telegraphed by the Associated Press and other coöperative agencies to all large cities. It may be of the greatest importance locally, but it is gradually cut down by the different agents as it gets farther away from its original source, until it reaches the other side of the world a mere sentence. But the pictures cannot go with the news. Even a thousand miles away they would arrive twenty-four hours too late for news interest. They must be on hand when the news comes in; and if they are not, they must be created. In order to keep up the supply of material, pictures must be obtained through constant clipping of other periodicals with a system of filing. To this must be added the activity and energetic insistence of reporters and press photographers, and, with some papers, "making up" or "faking."

By far the greatest number of pictures comes from clipping the hundreds of papers, magazines, and foreign illustrated weeklies that are received as exchanges. They are completely stripped of every picture, every item referring to any person, and all clippings of interest. Among the papers of the smaller towns only the Sunday

editions are looked over. The copyrighted American weeklies and magazines do not escape the general slaughter, although such stringent copyright laws as now exist cause even the newspapers to employ some precaution in using these pictures. A fine of from one hundred to five hundred dollars for infringement makes it necessary to obtain permission, which can usually be telegraphed for, before using material from this source. The system of clipping is so generally followed among newspapers that a mistake occurring in one paper is often repeated in another. Only a short time ago a picture of an actress, used in one paper for the Princess Cecile, appeared a few days later in another paper in the same connection.

The value of the mass of clippings and pictures that accumulates rapidly with time depends entirely upon a system of filing that will give immediate access to all the material on any subject. The classification consists of three great divisions: portraits and biographies, general pictures and clippings, and matter arranged by geographical location. This system varies in the different offices only in detail, everything being kept in envelopes, arranged either in cases or on shelves. Portraits are placed in their alphabetical order, with the exception of royalty, which are kept under the name of their country, and group pictures, which are kept together with cross-references to the single portraits. The general division has a comprehensive range of subjects, of which some idea can be obtained by the following list of envelopes: babies, bakery, balloons, balloon accidents, banks, baskets, baths, beauty, beer, bees, begging, bells,

Bible, bicycles, etc. This partial list shows that it is almost a complete modern encyclopædia brought up to the date of the latest newspaper. This division is in constant use in suggesting ideas for the Sunday papers and is often referred to by the artists in working up details of a drawing. The third group, arranged under the geographical heads, contains all views of places. Under the different countries and states appear such general heads as army, institutions, laws, etc., and all towns and cities. Probably nine tenths of the material stored up in this room — the "graveyard," as it is called by newspaper men — is never used, but the other tenth is so indispensable that it more than pays for all the trouble it costs.

An attempt is made to weed out the portraits by means of obituaries and yearly almanacs, and the list is added to by keeping a strict watch for men and women coming into prominence. New volumes of "Who 's Who" and lists from photographers are consulted, and many pictures written for. The library of the newspaper is usually well stocked with reference and illustrated books, naval annuals, royalty portrait collections, and books of foreign travel. The illustrations in these books are also included in the system by means of a card index. Old files of the illustrated weeklies are sometimes drawn upon and the woodcuts used as a basis for pictures of modern events. A recent wedding in the German royal family was illustrated by an old picture of the wedding of the Kaiser in 1881, with a few alterations.

Reporters well know the value of pictures, and are constantly on the watch for material to illustrate their

assignments. In securing pictures for some important news item, they would consider one or two days as time well spent. They are most likely to succeed in getting pictures from a private family when they can bring good news, and for this reason we usually see the portraits of people who have escaped in an accident. Their success might also be said to be in proportion to their "nerve." Bribing domestics has been tried with good results, and reporters are not discharged who have been known to take portraits without permission. Local material is nearly always supplied by the press photographers, who are reporters in a graphic sense and are given the usual assignments. They are not easily discouraged, and usually get the picture they are after, even though many difficulties must be encountered. People who do not care for journalistic publicity and will not pose for a picture naturally give some trouble. But the photographer can nearly always get a snap-shot in some way if he will endure some hours of waiting. After he has the print to show, he can explain that he regrets very much that it is a rather poor picture, but as the paper intends to publish some portrait in any event, it would be more satisfactory all around to have a good likeness. This is nearly always successful, and the victim submits to the inevitable with a good picture as a result.

Some of the more sensational papers, by cutting and pasting photographs and arranging groups to suit themselves, make the work of the regular press photographer doubly difficult by producing combinations that cannot be obtained by legitimate means. The pictures play

such an important part in such papers that their photographers are upheld in anything they may do, and even resulting lawsuits are welcomed as a good means of advertising. It would seem strange, if the papers that never hesitate to bring out all the dramatic possibilities of a bit of news, should lose an opportunity to make their pictures equally effective. All forms of "faking," such as cutting, pasting, and retouching, that could hardly be used in a magazine, are hard to detect in a newspaper on account of the rapid printing. Photographs can be cut and pasted together that make half-tones of undoubted fidelity. The ingenuity shown in devising some of these pictures often pardons the deception. To show how a paper may create a picture to go with a news item, one may analyze the illustration that went with an account of a Salvation Army revival in South Dakota. The artist cut the figures from an old photograph of the Salvation Army in the slums, and the old veterans from a G.A.R. parade in San Francisco served as a background of Westerners. The distance, showing a few houses and hills, was painted in, and no one ever doubted the genuineness of the printed picture.

The foreign weeklies have been of the greatest importance in forming the main source of all war pictures. Relying upon artists as well as cameras, they print many pictures wholly imaginary, but of remarkable fidelity. We must admire the cleverness of the newspaper artist who turned a picture of Madame du Gast being taken on board a French warship from a motor boat in the Mediterranean into a picture of a crew escaping from a sinking Russian battleship. We do not

criticize such a picture; it is probably as satisfying as some of the news that goes with it. Half-tones can be painted over, "doped over," and made into fairly good cuts. For instance, one vessel can be specially worked up in this way to illustrate some late piece of news.

Even the poorest half-tones saved in the clipping system can be made into good pictures. The method that is always employed is to make a "silver print" from a photographic enlargement of the original half-tone. This accurately gives the drawing and shading and only has to be painted over by the artist. The silver print is then faded out by immersion in sublimate of mercury, leaving the sketch better than the original. For work that is wanted in a great hurry a large silver print is made and cut into four or five sections and an artist put to work on each piece. The parts are then joined together and the work finished in one fifth of the time.

The most powerful factor on the pictorial side of the newspaper is the work of the cartoonist, and this is more familiar to the public than other features. From the time of the Tweed Ring, when Nast was offered $500,000 to go abroad and stop drawing for a year, the cartoon has become more and more a force through which the press reaches the millions who do not read editorials. The different cartoonists probably do not vary much in their methods of work. If a sketch is submitted to the editor for criticism or suggestions, as is always done in the case of political cartoons, where the policy of the paper must be considered, it is usually a rough pencil sketch. It is sometimes made carefully enough to be used as a basis for the ink drawing, or may be transferred

to another sheet to be finished in ink, as a copy may lack the spirit and freedom of the original. Although much material is submitted for the comic part of a newspaper, probably nine tenths of the work is done by the artists in the office. If they ever run short of ideas they have access to a reserve lot of jokes that have been sent in by men who grind them out by the hundreds. Comic pictures can always be divided into two classes; those that fit any conversational joke and those that contain a humorous idea in the drawing itself. The first kind is very common and is avoided if possible. Differing from the ordinary comic weekly, a newspaper endeavors to avoid anything that would offend any one in regard to nationality or race. An attempt is made to have something that will appeal to the children, so that a man will take the paper home.

The pictorial features of the Sunday papers take up about three fifths of the time of the art department. The rush that marks all newspaper work is not so evident with this edition, as all parts except the news section are ready two or three weeks in advance. The main idea is to make striking and effective pages by a free use of color and of decorative borders for the special stories and pictures.

The mechanical processes through which a picture must pass before it appears in print, often occupying several days in the ordinary commercial engraving house, are a matter of an hour or so in the newspaper engraving rooms. The simplest process is the reproduction of pen-and-ink or line drawings, by means of zinc etchings. The drawings are photographed, either enlarged or reduced,

and a negative made on a film on a heavy glass plate. The film is stripped and reversed on another plate and is then placed over a polished zinc plate, coated with bichromate of ammonia, and exposed to powerful arc lights. The action of the light hardens the exposed parts so that after the plate has been covered with ink and washed, the drawing is left on the plate in ink. The lines are dusted with a powder called "dragon's blood," which forms an enamel when heated and becomes the final protection of the lines against the acid in which the plate is immersed to etch away the exposed parts. This leaves the lines in relief; but two other etchings in the acid, with the "dragon's blood" protection before each one to prevent the acid from eating away the lines, are necessary before they finally stand high enough. The large blank spaces are routed out by a machine and the plate mounted on a metal base. In making half-tones from photographs, the process is the same except that the first negative is made through a screen of two glass plates, ruled with parallel lines sixty or eighty-five to the inch and set at right angles to each other. This breaks up the surface of the negative into dots.

The color plates for the Sunday comic supplement are prepared by the local force of each paper, although the drawings are often syndicate matter and appear in several cities at the same time. A proof of the drawings, in line only, is received by the different papers, several weeks in advance of their publication. This is transferred to four zinc plates, one of them being etched in the usual manner for the black plate. The original proof is then painted with the three primary colors, red, yel-

low, and blue, as a guide in making the color plates. Each plate is worked up separately on zinc to conform with the original colored sketch. The color is printed in dots of different sizes and shapes, lines and flat tints. Transparent sheets of celluloid composition called "Ben Day stipple" plates, with the pattern in relief, are inked and applied to the plate wherever the color is wanted. Take, for example, a picture with sky, trees, a barn, and roadway. The plate that is to print the blue is painted with a gum solution on all parts that do not require the color, in this case on the barn, roadway, and clouds. A stipple plate with dots giving the right depth of color is inked and pressed on the zinc plate. The gum solution is then washed off and the plate etched in acid, giving a plate that will print blue on the sky, and on the trees, where it produces green in combination with the yellow plate. This plate is treated in the same way; the sky and barn are painted out, a heavy stipple is used on the roadway and a lighter one on the trees. The red plate is painted solid on the barn to give it a strong color and possibly a light stipple is used on the distant trees to give a purple effect. By different combinations of these three colors all the intermediate effects are produced. More accurate register of the four plates is obtained by thus working direct on the metal than by any other method.

Newspaper printing differs in every way from book or magazine printing. Instead of flat-bed presses, printing on one side of separate sheets one thousand an hour, the newspaper presses are of the so-called "perfecting" type, printing from cylinders both sides of a continuous roll of paper at the rate of from twelve to twenty thousand an

hour. The work is all done from stereotypes, which are exact duplicates in one piece of metal of the page of type and cuts. They are made for three reasons: To give duplicates at once for the several presses, to preserve the type and cuts, and to take the shape of the curved presses. They are made by getting a mould of the page under heavy pressure in Japanese tissue, backed by papier-maché. This is hardened by baking and put in half cylinders the size of the press rolls. The metal that is poured in must be of an exact temperature, so that it will fill the smallest crevice before cooling, and yet not hot enough to burn the mould.

The tendency is toward an increase of the amount of illustration rather than toward improvement of its quality. Because of the inferior grade of paper used and the high speed at which the presses are run, any fine effects in the half-tone work are out of the question. Publishers aim to make up for this defect in the mechanical appearance of the paper by showing more and more enterprise and ingenuity in illustrating important news and making attractive the picturesque trifles that are included for their human interest. The papers are probably doing little by their illustrations to educate the public in artistic appreciation; but in interpreting and illuminating the news of the day, giving vividness to each story, making foreign lands seem real, setting a man's features side by side with his deeds, good or bad, they are teaching us that imaginative view of history in the making which means so much for social enlightenment and brotherhood.

MAKING MOVING PICTURES

By Bennet Musson and Robert Grau

ONE has only to enter a moving-picture studio to appreciate the difference between this new form of popular entertainment and the conventional drama. Plays, as understood since Elizabethan times, have been written, rehearsed, and acted; the film drama, on the other hand, is manufactured. A modern moving-picture plant presents a combination of the photographic gallery and the traditional stage. Like the former, it is, for the greater part, enclosed with glass; like the theater, it has its scenery, its carpenters, its costumed actors and actresses, and the raucous stage director piloting them through rehearsal.

Even where the moving-picture studio resembles the theater, however, things are strangely changed. It has not one stage, but two and sometimes three, on which different performances are sometimes taking place at the same moment. Its stages are not elevated platforms with orchestras in front, but are merely sections of the floor marked off by tape or a chalk-line. The scenes, as they are set for moving-picture "interiors," would never serve for the "legitimate" stage; as we watch them shimmer on the screen, they look sufficiently natural — as a matter of fact, however, they have only two sides. The scene-painting likewise has a character all its own; it is not done in colors, but it is in black and white. The

moving-picture footlights, if they may be so described, are far more dazzling even than those demanded by modern musical comedy. They consist of gigantic arc or Cooper Hewitt lights; instead of drops and ceilings, another row of Ariosto lamps pours an intense mass of white light down upon the performers.

The actors and actresses themselves, though in practically all cases taken from the "legitimate" stage, have undergone a weird transformation.

"Make-up," in the moving-picture studio, is apparently a distinct art. Such artifices as highly rouged lips and cheeks, penciled eyebrows, and painted lines intended to accentuate particular features, play no part in moving pictures. As the figures on the screen are usually magnified to heroic proportions, and as the camera simply reproduces the things before it and does not blend its several impressions into a generally pleasing illusion, the "make-up" which is deemed indispensable on Broadway would make hideous the most beautiful human countenance. Almost the only useful device is whitening the face. Red and its correlated colors photograph dark; and a gentleman with a florid complexion and a highly rouged lady would look almost like negroes when "projected." The actors and actresses, therefore, seem like unfamiliarly attired Pierrots and Pierrettes — an effect that is fairly ghostly, and not at all, as seen in the flesh, suggestive of beauty.

All these things are explained by the fact that the moving-picture show, as rehearsed, has only a solitary, single-eyed spectator. This one spectator sees more than a million human eyes can comprehend. The

most ultra-microscopic details never elude the vigilant camera. It sees everything as it is — it is the one infallible critic. Before the camera, one cannot take an eighteen-year-old girl, put a wig on her head, make a few black marks on her face, and call her an old crone. Similarly, one cannot artificially transform a dowager into an *ingénue*. In this animated play the actor and actress must be, in real life, just about what they are supposed to be on the stage. This does not mean that the actor cannot play a variety of parts, — there is one man who has played not far from a thousand, — but in age and essential appearance, at least, nature and art must coincide.

The beginning of the moving-picture play is its creation in the brain of the scenario-writer. Hundreds of men and women are writing motion-picture plays to-day, but, as in all forms of literature, success comes to very few. There is a great demand, however, for this type of play. In the United States alone, not far from one hundred new moving-picture plays are put out every week — some five thousand in the course of the year. The appetite of the public, and consequently of the managers, is insatiable. In many cases the writers are well paid; perhaps fifty dollars a scenario is an average figure, but "big" people get higher prices, in some cases as much as a thousand dollars for a single film. These rates of compensation have attracted several successful writers of "legitimate literature," as it might be called. There are even "correspondence schools" to teach the unpracticed how to acquire this art. Some studios have regularly salaried scenario-makers and adapters of other

people's ideas. What has been said of all plays is similarly true of scenario-plays; they are not written, but rewritten. Most ideas submitted are too commonplace and obvious. The everlasting demand in moving-picture literature, as everywhere, is novelty. And its essence is that it shall be pictorial. It is a succession of scenes — a high-class dumb-show. The effects must be broad and pointed, and easily grasped by the average mind; there is no chance for the psychological drama in an electrical theater.

From its creation in the scenario-maker's mind to its projection, however, is a long stride — from three to six months or a year. We sit in the theater and see a thousand-foot reel, comprising twenty or thirty scenes, run off in fifteen minutes. We seldom realize that it takes a week, two weeks, sometimes two months, to provide this quarter of an hour's entertainment. Companies frequently travel all over the world to find a proper setting; the proprietor invests two thousand, five thousand, and sometimes as much as fifty thousand dollars on a single play. It is not the cheapness of making the pictures that attracts the producers; it sometimes costs far more to "raise the curtain" on half an hour's entertainment in the animated theater than it does to produce the most extravagant musical show. And many of the studios are more elaborate than anything known in theaterdom.

Indeed, they have to be. Drury Lane produces one or two pantomimes a year; these places put out three or four or five new films every week. The Edison studios in New York cost one hundred thousand dollars to build. The Selig studio in Chicago employs regularly five hun-

dred people. It has enclosed two or three adjoining acres for "exteriors" — as scenes taken outdoors are called; and here it has even manufactured hills for military and woodland spectacles. Its establishment at Los Angeles strikingly illustrates the great natural resources used in cinematography. One of its "properties," used for elaborate sea events, is the Pacific Ocean; for mountain scenes the Sierras are part of its equipment. Within a comparatively short journey is the Great American Desert, as it used to be called in the old geographies; near by are the California forests; whereas, if the Selig Company is producing a fairy play and wishes a real fairyland, it can easily use sections of the Yosemite Valley. The Selig Company, incidentally, has a wardrobe of more than seven thousand costumes! The Metropolitan Opera House can hardly rival this.

It is the business of the stage-director to assemble all these resources, human and otherwise, in the way that will give the most pointed effect to the scenario-writer's idea. This stage director is the one studio authority who recalls his prototype of the stage. In his autocratic and frequently ungentle manners, his gesticulations, his enthusiasms, his sarcasm, his Homeric laughter, and his unstinted praise for an excellent piece of work, he brings back once more the old familiar figure.

Necessarily he is the absolute dictator — camera operator, stage-carpenters, property-men, actors, actresses, even the scenario-writers, are his peculiar puppets. He has plenty of excuse for activity and even nervousness. Rapidity of motion is essential to his success; he works in seconds, not hours. Each minute rep-

resents 360 photographs — a piece of film sixty feet long. In a regular stage play, a mistake can easily be covered up by improvised words and "business." Not so in the animated theater, for the implacable camera stands there, ready to immortalize every "break."

This probably accounts for the bustle that marks all the preparation. Every picture, of course, is carefully rehearsed before it is taken. Many directors have the habit of keeping the performers in the dark concerning the plot, believing that the element of suspense thus introduced actually enhances the dramatic interest in the production. He therefore assembles his performers, tells each one how to dress and the particular kind of part assigned to him, and describes the scene. There is another thing about the rehearsals that seems strange when we remember that the picture show is commonly described as the "silent drama." For, in rehearsal and during photography, the play is not silent at all. The French scenario-writers insist on writing out dialogues for the actors to speak, as in a conventional drama. In this country the stage-director usually makes up the lines as he goes along, or the performers improvise. The wisdom of this procedure, of course, is that the actual speaking of words adds to the naturalness of the acting, and especially of facial expression. The effect at a "movie" rehearsal, however, is startlingly different from the action which takes place on a screen. A riot scene, which is silent in the theater, is a terrific hubbub in the studio. A beautiful lady, dragged into captivity by Indians, makes no noise when "projected"; but there is a bloodcurdling yell at rehearsal.

One of the stage-director's troubles is what is known as "camera consciousness." The player must never recognize the fact that the camera is present; he shows himself a greenhorn if he once looks at it. If he does this, he will apparently be looking at each person in the audience when the scene is projected. This is the chief difficulty with child actors—it seems almost impossible to get one who is able to keep his eyes off the camera. "Supers" are notorious for this defect.

In the course of the rehearsal, the director works over the play, cuts it, occasionally throws out whole scenes, and radically rearranges others, so that the author, when he finally sees it produced, is somewhat mystified. In the director's eye, the play is just so many feet of film. He calculates in advance how many feet each scene will take, and rehearses for time as well as for dramatic perfection. If the company takes forty seconds to act an episode that the director has planned for thirty, the rehearsal continues until this defect is overcome.

After several rehearsals, sometimes extending over a day or two, the scene is ready for the camera.

"Lights!" shouts the director.

Immediately dozens of arc-lights, at the sides and above the stage, burst forth. However brightly the sun may be pouring through the glass roof, this additional illumination is always used. Its effect upon the performers is far from enjoyable, for the heat from it is intense.

"Everybody ready?" the director asks. "All right, now! Steady! Shoot!"

This last word is addressed to the photographer. The

whirring immediately begins, and now likewise the director brings his finest energies into play. "Get into the picture, Miss Smith!" "Get off the stage, Mr. Jones; not so fast!" "Hurry up, there, Robinson!" "All look happy; this is n't a tragedy we're playing; brighten up!" "Drop your eyelids, Miss Brown!" His chief anxiety is to keep everybody within the focus chalked out on the floor. If the actor merely moves his arm outside, an essential part of him leaves the picture — is "decapitated," to use the technical word. Any one would imagine that the players would get confused at the director's hurried instructions, especially as he commonly emphasizes his remarks by jumping up and down. All, however, quietly accept his emendations and go on with the play. After forty or fifty seconds, — about the average length of a scene, — the director abruptly turns to the operator.

"Stop! Lights out!"

The clicking ceases.

"All over!" And the players break up, usually much relieved to get out of the heated little circle.

Many times, however, they immediately form a new group in the same setting. This next scene may not follow consecutively the one just taken — may be ten or a dozen scenes after it. But for convenience and economy, all episodes that take place with the same scene and costumes are filmed one after another.

The burden of success is now shifted to the developing-room, which is not far away. In a few minutes the operator rushes in with a few feet of wet films. "It's all right," he says, holding it up to the light for general in-

spection. In a few days a thousand feet of film — about twenty minutes' entertainment — is developed, printed, and wound on a bobbin. In nearly all studios, the players attend in a mass when the play is privately screened — a kind of dress rehearsal. This is one of their regular duties. They come with pads and pencils; as scene after scene reels off, they write their criticisms, and, without signing their names, hand them to the director as they go out. The play, as finished and approved by the play-director and performers, is then exhibited to the studio film committee. Again approved, it goes before the censorship board. Not until this latter body has given the new play its "O.K." is it definitely ready for the market. The technical word for this is the "release."

The things done on the stage — the "interiors," as they are technically called — do not compare, in energy and enterprise, with what is done in the "outside" work. Every morning a large automobile pulls up in front of the studio, takes on a small army of white-faced cowboys, or soldiers, or farmers, or whatever characters the piece calls for, and drives into the country. The cinematographer who accompanies this party has a hard day's work in hand. In the studio his tripod is securely fastened to the floor; on an outside trip, however, he knows not what adventures will befall. Sometimes he has to photograph sea scenes standing up in a rolling motor-boat; at other times he makes his pictures from the top of a moving freight-car. An especially exciting experience of this kind was that of the adventurer who photographed the "boiling pot" of the Vic-

toria Falls in the Zambesi River. His associates on the bridge lowered him four hundred feet by ropes, and held him suspended within a short distance of the spectacle while he turned the crank of his machine and got his picture.

To get a realistic *milieu* the producers will spend any amount of time and money. In the United States, especially, the demand for actualities amounts almost to a craze. "Uncle Tom's Cabin" is filmed among such vestiges of plantation life as still remain in the South. One producer sent a company of fifty people to California, where they spent nearly six months rehearsing Helen Hunt's "Ramona." The "Leather Stocking Tales" are moving-pictured among Cooper's native lakes and forests in New York State; and "real Indians" — who greatly enjoy playing before the camera — are pressed into service. The European demand for cowboy and ranch scenes, which the American producers have met on a large scale, has led to the preservation of the rapidly vanishing frontier life of the West. American producers, however, in their search for realism, do not limit themselves to their own country. One company has produced many of Boucicault's Irish plays — "The Shaughraun," "The Colleen Bawn," and others — in all their natural Irish settings. "Rob Roy" is played with the actual Scottish Highlands for a background. In depicting the execution of Lady Jane Grey, the thousand-year-old Tower of London furnishes the setting. An American company has just returned from London, where it filmed Mr. Pickwick amid veracious English surroundings.

The producers also rival one another in feats of sensationalism. A year ago the Thanhouser Company, in New Rochelle, purchased an old house and burned it down, in order to show its patrons what a fire really looked like. It impressed, as a temporary stock company, the local fire and police departments and a considerable part of the city's population. Another company, filming a railroad accident, purchased several old cars and rolled them down an embankment. To secure an explosion at sea, an enterprising manager purchased an old schooner, turned it adrift, and dynamited it. The Edison Company once staged a riot in a small country town. They did it so perfectly that the local constables rushed in, arrested the rignleaders, and put them in jail. The players suffered these slight discomforts gladly, inasmuch as the arrival of the authorities had increased the effectiveness of the picture. Indeed, the widespread activities of the moving-picture man have added to the perplexities of the police. A gang of burglars breaking into a bank now hardly attracts passing notice; in certain rural sections, a man can hold up a trolly-car almost with impunity. In the West, a daylight attack by Jesse James desperadoes upon an old-fashioned stagecoach hardly causes a ripple of interest — they are merely being filmed. Real criminals, when caught red-handed, have sometimes escaped on the plea that they were motion-picture performers. On the other hand, genuine camera actors who make this excuse are frequently hustled off to jail. The police have heard that story before! Occasionally the picture actors return the compliment. A gentleman in an American town who

fiercely objected to having his house cinematographed, one day felt a firm grasp on his collar and was informed by a policeman that he was under arrest for breaking the peace. He was badly scared for a few minutes, until the policeman revealed his identity: he was merely acting the part. But he had kept his prisoner quiet long enough to let the photographer get the desired picture.

A director shows his enterprise and cleverness in his manner of taking advantage of unforeseen events. These sometimes happen in the course of the play itself. In one case the studio in which a play was being filmed caught fire. The company ran around desperately in their attempts to escape. The operator at once turned his machine on the actors, and so obtained a useful and thrilling film. When anarchists created a disturbance in London two years ago, the cinematographer was one of the most interested spectators. He also was promptly on hand when the Paris Apaches built barricades and made targets of the gendarmes. Although the camera man was fully exposed, the beleaguered criminals carefully avoided shooting at him; so strong is human vanity!

After these performances the experiences of the everyday moving-picture actor seem somewhat tame. Yet many do have somewhat lively times. When the Edison Company attempted to reproduce scenes in the Boer War, one of the actors dropped a lighted match into a barrel of gunpowder. There was a loud explosion, though no one was killed. Louis Gasnier, the general director in this country of Pathé Frères, once went to extremes to get a picture of a runaway horse. Under

a two-wheeled wagon he had fastened a coffin with the end knocked out. Gasnier, dressed in black, with black gloves and a mask, — the idea being to render himself invisible, — crawled into this gruesome receptacle. From this location he proposed to drive, with invisible steel wires, a spirited horse. The scheme worked so admirably that part of the apparatus broke, and the horse really ran away. Mr. Gasnier was thrown out, knocked senseless, and spent two weeks in a hospital. As soon as he recovered, however, he had the apparatus reconstructed, climbed into his coffin, and this time secured the picture.

Two years ago the Vitagraph Company was staging a play, one scene of which represented a young woman falling from a boat into the water at Brighton Beach. The young woman was to wear a white dress and white hat, and carry a parasol. The director telegraphed the details to Miss Florence Turner, one of the best-known moving-picture actresses in this country, who appeared, dressed according to programme, at the appointed time.

"By the way, how well do you swim, Miss Turner?" the director asked, just as she was about to perform the act.

"I don't swim at all; in fact, I've never been in the water. But I'm not a bit afraid," she replied.

The director, looking at Miss Turner much as he would at an escaped lunatic, ordered her home. But she insisted. It was a rescue scene; there were three good swimmers ready to pull her out: what possible danger could there be? After a time Miss Turner carried her point, and fell overboard as natural as life —

and sank quite as naturally. Having never been under the water before, the sensation of cold and saltiness was not entirely delightful. The descent seemed endless; but finally Miss Turner felt herself rising. When she reached the top, however, the three rescuers were nowhere near, and down she went again. When she came up the second time, one of the men grabbed her. They towed her back to shore, where she thanked and blessed her rescuers in true moving-picture style.

The producers, however, now generally deprecate performances of this kind, and in the future there will be few such stories to tell. Real enterprise now finds its expression, not in dare-devil feats, but in things really worth while. A few months ago a manager paid Sarah Bernhardt $30,000 for posing in "Camille." The pictures, however, were a failure — another illustration of the fact that the most experienced theatrical artist has something to learn before she can play to the camera. Madame Bernhardt was asked to do the thing over again; but she demanded another $30,000! She received that sum for posing in "Queen Elizabeth." Thus it is no longer true that the actor's fame is writ in water — that nothing survives but his reputation. With the phonograph immortalizing his spoken word and the moving picture his physical counterfeit, he now goes down to posterity. What would not the present generation give for similar presentments of Garrick, Fanny Kemble, or Edwin Booth.

The English producers show wonderful enterprise in obtaining pictures of events that especially appeal to English patriotism — the coronation of King George,

and the investiture of the Prince of Wales at Carnarvon Castle. In London the royal procession to the Abbey was shown on the screen before the return journey to Buckingham Palace had begun. This was made possible by relays of operators and taxicabs along the line, rapid development, and special trains. The investiture of the Prince of Wales was exhibited on the evening of the day that the event took place. In this case the films were developed, washed, dried, printed, and prepared for exhibition on a special train.

These performances emphasize one of the greatest uses of this new art — its work in general education. Dr. Comandon, a French scientist, has already shown what the combination of microscope and moving-picture camera can achieve in physiology and bacteriology. For the first time he has given the world a picture of the blood coursing through the veins. He has likewise photographed one of the greatest medical discoveries of the age — the action of the white corpuscles of the blood which is known as "phagocytosis." The discovery of this phenomenon is the thing that will immortalize the name of Metchnikoff. Metchnikoff discovered that the white corpuscles protect the blood, and consequently the body, from injurious foreign substances. They are the body's scavengers, or guardsmen. If any foreign substance enters the body, these white corpuscles, or phagocytes (cell-eaters), as Metchnikoff calls them, at once surround and absorb it. Their chief function is to protect us against bacterial diseases. If typhoid germs get into the blood stream, the white corpuscles immediately begin de-

vouring them. If they succeed, we escape the sickness; if they fail, then we are forced to take to our beds.

When Metchnikoff first announced this discovery, scientific men were skeptical, though now they generally accept it. If there are any doubters left, the moving-picture machine can satisfy them. For, on an enormously magnified scale, Dr. Comandon has shown the phenomenon of phagocytosis in actual operation. What Metchnikoff, in the course of a lifetime, painfully worked out with the microscope, appears on the screen with all the realism of a dog fight.

A patient and ingenious Englishman, Mr. F. Percy Smith, has performed similar marvels with plant and insect life. He has succeeded in producing a film that shows a flower developing from seed to blossom. One of his most popular achievements is a moving picture of a chicken hatching from the egg. An Italian has cinematographed the development of a butterfly from a caterpillar; he even filmed the supreme moment of its emergence from the chrysalis.

In view of all this, it is perhaps not strange that Superintendent Maxwell has requested the Board of Education to put one hundred moving-picture machines into the New York public schools. In educational work, indeed, there seems no limit to its usefulness. Already social workers are using films to emphasize important facts of sanitation and hygiene. The ravages of tuberculosis, the dangerous activities of the ordinary horsefly, the preventability of blindness in babies — subjects like these only suggest the educational resources of the moving picture.

THE FARM-BOY WHO WENT BACK

By H. Gard

JOHNNY WORTMAN hated the farm. He rose at half-past three or four o'clock every morning, fed and curried his team, and ran to the pasture for the cows. His bare feet stung, and he would warm them where the cows had lain. He turned the cows to the calves, milked, drove the cows back to the pasture, and breakfasted. By half-past five he was in the field to plough, to harrow, or to cut hay; or in the truck patch to hoe, to pick berries, or to worm the cabbages; or in the potato patch with a brush to fight the beetles.

Then, on top of all this, his Sunday-school teacher pestered him to learn the names of all the books in the Bible, to memorize the Golden Text, or to read about "Bezalel, the son of Uri, the son of Hur, of the tribe of Judah." "And with him was Aholiab, the son of Ahisamach, of the tribe of Dan," an engraver, and a cunning workman, and an embroiderer in blue and in purple and in scarlet and in fine linen. After the reading, the teacher would ask to what tribe did Bezalel belong? And so on down the parched and barren way. Johnny could not remember all those names and dates and what the fellows did. Every time he made a break, Artie Eely would thrust up his hand and arm like a goose's neck and nearly twist off his seat in his enthusiasm to let

the teacher know that *he* could answer the question properly. Then the teacher would say: "Artie is the only smart boy in the class."

Johnny decided that he would run away, so he tied up his clothes in an old shirt and left at midnight. He ran through the orchard and hopped the fence into the pasture. He ran over a calf, which scared him nearly to death. The night was darker than he thought it could be, so he started back to the house. In going through the yard he ran into "Shep," who was chasing a cat. In the scramble, his mother heard him.

She came downstairs, saw his bundle, and knew what was up. She closed the door and he felt a "scorcher" coming. She told him to tell her all about it, and he did.

She told him she knew that they had a hard life of it. It had been that way ever since they had bought the farm. There was the interest on the Modesitt note, the taxes, the mortgage, and many other smaller "dribs." The hogs had died of the cholera; the best team had been sold to pay off a note that threatened trouble, so they had nothing left to work with but two old teams of skin and bones. She too longed for a different life, yet she found a silent joy in the stubborn work and in rearing her house of little ones. She said that his going away would make her very sad; besides, his little sisters would have no one to take them to school on the cold winter mornings. He untied his little bundle.

Johnny's father was n't a good manager. The mortgage lingered, and the Modesitt loan and other "dribs" had a way of growing by the compounding of interest. His father "went security," and some neighbors whose

notes he endorsed used the borrowed money to buy things that he had to do without. Once in a while the sureties had to pay the notes.

His mother died — worked, worried, and tired to death. Johnny felt free. Surely the big outside world could n't be harder. He jumped on a freight train, helped the fireman shovel coal, and slept in the tender. He landed in New York, and in two days was working on a tugboat as roustabout, washing dishes, scrubbing, etc. It was a new sensation. A few weeks later he got a job on an excursion boat plying on the Hudson between New York and Newburgh. Clubs would charter the boat for a day or two. Johnny waited on the table, served the drinks, passed the cigars, and helped himself to whatever he wanted, for the clubs footed the bills. It was like finding manna — board free, wages thrown in.

He quit the excursion boat for an ocean steamer sailing to Brazil and the Barbadoes. The outgoing vessel carried machinery and canned goods, while the incoming brought coffee, Brazil-nuts, and raw rubber in nuggets that looked like clods of earth. But Johnny tired of it and beat his way home again.

The farm was just as distasteful as ever, so he crawled under a New York Central sleeper bound for St. Louis. He rode on the trucks from St. Louis to Kansas City, then to Denver, then to Colorado Springs, where he worked a few days, then on to Salt Lake City, San Pedro, Los Angeles, thence by boat as a stowaway to San Francisco. As he left the vessel the sailors yelled at him and called him "Dago." He cleaned brick; the pay

was small, the hours long. He had to compete with Italians, Japanese, Chinese, consumptives, and many others in poor health who were willing enough to work for bare necessities.

He went on to Sacramento and thence by sleeper-trucks to Portland. He could n't find a thing to do there. A man on one of the city jobs told him he could get work if he had money. Having no money, he boarded a train on the Oregon "Short-Cut" for Salt Lake City. He rode the trucks, in between the mail-cars, in the blinders, or on top of the coaches. In going through a tunnel one foot piled on the other, a projecting rock struck his toe. It stung so that he nearly rolled off; he did n't ride on top any more.

At Salt Lake City he found work in a restaurant. He worked every day and Sunday from four in the morning until nine and ten at night, with never a vacation, never an hour off for more than a year. He planted two hundred and fifty dollars in the bank during the time. Disgusted, he started home, using his truck and blinder pass. This was a hard life, too, — full of cold fingers, sleepless nights, thirty-six to forty-eight hours at a stretch without food, many hours without drink. He was only a laborer. The great outside world had no more contentment than the old farm. So back to the farm.

He went at it with a vim. He rented a piece of land, and raised six hundred and eighteen bushels of wheat. But he was n't enraptured with the farm yet — too much hard work, no leisure, no regularity of prices, too much uncertainty. Then he became a school-teacher,

but in teaching he found himself bound by precedent. Method was supreme — the Socratic method, the teaching ideas of Plato, Aristotle, Pestalozzi, Froebel, Herbart, Hegel, applied psychology, history of education, Spencer's Philosophy, apperception, correlation, experimental psychology, lengthy treatises on how to make the idea shoot. Johnny could n't harmonize with the system, so he quit.

He then decided that he would be a business man — learn the game and have a business of his own. Then he would have money, a coach, a box at the theater, servants, a big mansion on a fashionable street, fine clothes, prestige, honor, the whole galaxy of luxuries. Back to New York he went. Men looked up from their desks and asked: "What can you do?" He was "up against it." Finally he ran across a gentleman who dictated his letters to a phonograph. Johnny told him, "Try me three weeks, three dollars a week." He rented an old machine and practiced till three o'clock A.M. At the office the next morning he stuck the tubes in his ears and "lit in." But the old typewriter ran like a log-wagon. Ten o'clock that night found him copying the letters of the day in the letter-book.

He had only fifty cents left and it was a week till pay-day. He told the landlady, but she said that she would n't trust anybody; so he slept in a delivery wagon, in an old boat, in a shed. He bought a loaf of bread and some bananas every day; water was free. Thursday he stranded. Could he stand it till Saturday evening? It was like pulling teeth. Saturday he got his three dollars. He had to have hat and socks. That took

$1.15, leaving him $1.85. He must eat, but he could get along without a bed. His old suit went off on a tear, so he had to buy at a pay-us-a-little-at-a-time house — $7.50 for a suit, payable $1.25 down and $1.25 a week. He could n't have butter on both sides of his bread and snore on eider for what he had left. So he stuck to the eatables and shifted for sleeping apartments. Anyway the nights were getting warm and the top of an old shed did n't go so bad. Worse things could happen.

In three months his pay was $4.50 a week. In six months it had another jubilee and danced to the tune of $6. He could see the promised land. In a year he was docketed for $10 a week. After that the advances came just as often, but the increase was only $1 each time till it got to $20; then he got a $5 raise every six months. He knew nearly everything about the plant and everybody from the manager to the fellow who stole junk. He worked from three in the morning till eight and nine at night. His salary was $60 a week now, but where was this advantage over the farm? There was no time for recreation, no superabundance of fresh air, no cozy nooks, no inviting streams, no smoke-free sunshine. He beat the bushes for an easier position, worked for a millionaire, then for a multi-millionaire, then took the speculation fever. He put in all; result: not only did he lose all his money, but his health was cracked. The doctors said, "Tuberculosis."

Undaunted, he sailed in again. The soil called him back. There were glowing accounts of bumper crops in new sections of the country. The claims were writ big on billboards and in street-cars, special letters, booklets —

the very flower of the engravers, printers, and lithographer's arts; Italian climate, territory lavishly endowed in fruits, soil, forage, grasses, river and mountain scenery, mines, and timber.

Johnny dabbled a little and lost money. One day he saw an advertisement reading: "Railroad lands at $2.50 an acre. You can buy 160 acres, no more. The tracts are heavily timbered, scoring from five to sixteen millions of feet of lumber a quarter section. Finest agriculture and fruit region in the country."

The land was in litigation. The Government was trying to compel the railroad company to sell the land. The agent said the land would have to be sold, and he was representing the attorney for the railroad company, registering applications for the land.

"You see, it's this way," he said. "Only one application will be registered for each quarter section. You select your lot, pay me $75, and that pays all fees — the registering of the application, the filing of the deed, attorney's fees, etc. Then you pay no more until the land is deeded to you. Decide the matter at once, for next week I am going to Chicago to open an office there."

Johnny did n't "bite," but wrote to the clerk of the county in which the land was situated. The clerk replied: "There are enough applicants on file to cover all the railroad lands three or four times. It is a scheme of locaters who are making money out of it."

Johnny's chase wound up with a nugget of wisdom and a determination to go back to the soil. From it he had been driven by drudgery, the long hours, the lack of

social uplift, and the barrenness of inspiration. The farmers were the underdogs, throttled by the stock gamblers, fleeced by the merchants; the city allured with its higher wages, shorter hours, its paved streets, water, gas, and electrical systems, its theaters, moving-picture shows, parks, scenic railways, trolley-rides, music, churches, and the weekly pay-day with half-holiday on Saturday. There you wore better clothes, saw things happening, and could see promotion after promotion to him who proved worthy of the laurels. Advertisements lent a charm: "Learn Proof-Reading—$25 to $50 a week; demand exceeds the supply! $25 to $50 (even $100) a week for advertisement writers! $1000 to $10,000 a year sure if you master Softie's course in salesmanship; hundreds of positions open for the spring rush; send for free booklet! Be a Harriman, a Hill, a Burke, a Choate, or land on the Supreme Bench by Spare-Time Study." Pictures just as glowing might be painted about the farm, pictures that would make you drunk with enchantment.

Toil and brains applied to the soil would bring wonderful results. Had n't Mr. Burbank proved it? Drunk with this idea, Johnny went back to the farm with the determination to study and to understand. He started with geese. He became a regular goose about goslings and ferreted out the goose law so that he could raise every gosling hatched. He knew the difference between the African, the Emden, the Toulouse, the wild, and the Chinese. The dewlapped African is prolific, early, and fine-flavored, but pugnacious and quarrelsome. The Emden lays only about twenty eggs a year, while the

coarse and flabby Toulouse brings the record up to forty a year. The wild goose lays only five to eight eggs a season, but the eggs are invariably fertile and bring forth strong, vigorous goslings. Johnny combined strains till he had not an African nor an Emden, nor a wild, but a *goose* — a top-notcher for flavor, earliness, size, tenderness, fecundity, feathers, profit. He shortened the fattening record a fourth by a judicious mixture of grass, grain, roots, cabbage, beef scrap, and pure water, so that he could market at flood-tide. He was becoming a creator; the joy of achievement filled his sails; no drudgery now, no city-lure distracted, no reports of fabulous profits uprooted him. It would take a standing army to drive him from the farm.

Then he turned to seed-corn. He read, experimented, selected, combined, and eliminated till he struck thirteen on the how to go at it, very nigh touching perfection, but never quite reaching it. Watch him pick out the stalks that look thriftiest, hardiest, greenest, and those that have large, spreading tentacles at the roots. He ties a string to those stalks. In a few days he detassels them before the pollen forms, to prevent self-fertilization. The next year he plants these selected ears in rows to themselves, one ear to a row, three grains to the hill. If only two of the grains grow he will not select seed from that hill, because of the low vitality. Summer comes; he selects the strongest plants, detassels some for mother plants, and leaves others for father plants. He ties a paper bag over the mother ears so that pollen from weak and promiscuous stalks may not fertilize his seed-ears. When the pollen on the father stalks ripens,

he hand-fertilizes the mother ears, then ties the paper bags on again. For his seed he selects only the very best ears from the mother stalks. Each year he gets a finer strain, more uniform, more productive. Each year a little better, but never quite perfect — see? When the ears begin to ripen, he gathers the seed. It is carefully, thoroughly dried and is kept in an even temperature through the long winter, for constant freezing and thawing play havoc with delicate corn-germs the same as with tender toes and fingers. He gleans more gold from his cornfields than the farmers of the drudgery school. They come a-running to Johnny to see what he is doing and pay a premium for his corn.

Next he got the tiling fever. Wiseheimers told him that tiling would drain the land so quickly and so thoroughly that in dry times his crops would suffer. But Cornell Bailey put a bug into his ear. He told him to tile his clay and other soils that were not porous and naturally well-drained. It enables the surplus water to run off, leaves the soil friable, so that you may break it earlier and plant earlier. The roots of plants do not grow down below the line of standing water in the soil. In the spring the water stands only a few inches from the surface in untiled land. The roots grow down to this standing-water and stop, for they cannot stand wet feet and cannot grow where there is no air. Since the roots cannot grow down, they spread out close to the surface. Tile the land, and the water-level sinks down three or four feet. The plant roots keep delving and digging and stretching till they reach it. The plants have such enormous root-systems and grow so fast that

they choke out the weeds. Corn roots will grow down three to five feet if you give them half a chance. If drouth comes, it takes a long time to evaporate all the moisture down three or four feet below the surface, but down there is where the roots are growing on tiled land.

Johnny spent every dollar that he could spare on tiling his land. His crops increased in yield as the land became honeycombed with percolating channels to the tile below. His land became more fertile, full of nitrogen and oxygen; he planted his crops earlier; they ripened earlier; they grew so rapidly that weeds were choked and quality was high. His acres smiled and laughed bumper crops, and their master basked in the joys of discovery and achievement.

He learned also to grow alfalfa on his clay soil. Alfalfa is a mortgage-lifter, a matchless fertilizer, unequaled for stock, making the horses sleek and the hogs fat as butter-balls. It fills the egg-basket and the milk-pails; pigs squeal for it; colts whinny for it; and it knocks chicken-lice seven ways for Sunday. It is a marvelous grower, giving three to nine crops of sweet hay a year. It works all the time, Saturday afternoon, and Sunday in triple shifts. Its stems and leaves and nodules gather from air and sunshine loads of warmth and nitrogen and store them in the soil. The roots go down into hard-pan many feet, making a million channels through the soil so it may become thoroughly aërated and drained.

His Cheviot sheep told of the days when they browsed the Cheviot Hills, which dissever England from Scot-

land, and how they got their sharp noses from picking the grass from between the rocks. Those with the sharpest and longest noses could get the most grass, hence thrived better than the others; and so, long noses got to be the only style. His Shropshires came from the shire of Shrop in merry England. Their fleece is dull white with a fringe of brown.

Everything on Johnny's farm is alive with interest and history. He loves the farm; it is his life. No heaps of manure pile up at the rear of his barns to seep away in waste. He uses something or other to retain the nitrogen and hauls it to the fields where it may make humus and liberate new plant foods. He is intensifying. He makes as much from forty acres as others make from two hundred and forty. His land is fertile, well-tiled, requires less labor, fewer steps, less up-keep, less machinery.

He saves the waste in other ways. From ten to twenty per cent of the egg-crop rots every year. Kansas loses ten million eggs a year, a loss of $4,500,000. An hour of hot sunshine on an egg ruins it. Egg-shells are porous, evaporate with age, and drink in rank poisons. Johnny gathers his eggs twice to three times a day; he markets them two to three times a week. They go to the consumer fresh, nourishing, unevaporated, contagious with health. None of his eggs go to storage.

Johnny left the farm to get away from drudgery only to find that the city, too, belongs to the great work-a-day world. He came back to the farm prepared for contentment. A new dispensation is coming. The fields are beginning to feel a new fertility because a loving

hand tills them; the birds bask in the fervor of a new appreciation; the song of the reaper is set to new tunes. The new farm means a new city, larger, cleaner, better fed.

"DOCTOR SUCCEEDED NEVERTHELESS"

(*Abridged*)

By W. W. Peter

TO the west of the western edge of a great lake in Hunan Province, China, is Chang-te, a city whose inhabitants have never been numbered. There may be 200,000 in it as some estimate. Perhaps there are 50,000 or 75,000 less. No one knows. Around this city in the valley of the Yuan River is a huge wall of mud, brick, and stone, higher by ten feet than most of the houses within. This wall was built to protect the people from the spring and summer floods. In low water the river flows past the city. In flood water it flows past and around the city. At such times the city becomes an island, and to a man high up in an aeroplane would resemble nothing so much as a huge washtub full of living creatures resting in a body of muddy water.

To this city in 1899 came "Doctor Succeeded Nevertheless," whose other name is O. T. Logan. Originally from Illinois, he came to China to live and work as a medical missionary.

Less than two hundred years ago, when "foreign devils" first came into China, the Chinese tried to restrict contamination to the port cities. Foreigners were prevented from entering the interior, which for years remained a locked-up, mysterious country. But gradu-

ally the barriers were broken down by commerce, Christianity, and cannon, the three strong arms of Western civilization. Through the central Government on the one hand, and each of the eighteen provinces on the other, the entire country was opened to foreigners. But the Province of Hunan was the last one to open its doors.

About this time, 1897, Dr. O. T. Logan and his wife arrived at I-chang, Hupeh, where they spent a year studying the language and waiting for a favorable opportunity to go south into Hunan. In those days there were no steamers running so far inland and when they decided to venture into Hunan they had to travel by means of a slow-going houseboat that was propelled by long bamboo poles, heavy sweeps, and wind.

When the party got as far as Shi-Shau, on the border between Hupeh and Hunan, they felt the temper of the people. For centuries the Hunanese had been spared what they came to consider the blight of intercourse with foreigners, and they gave way grudgingly to the trend of the times. Although the doors of the province were officially declared open, practically they were still shut in certain cities and only a crack open in others.

The Chinese in this houseboat party advocated turning back. It was plain that foreigners were not wanted. At this rather critical stage in their journey, the doctor succeeded in giving relief to a woman who had been brought to him. While eating her rice she had swallowed a needle. First husband, then relatives, then Chinese doctors, had reached down for the needle and failed.

In desperation they took her to the river-bank to the boat on which the "foreign devil" doctor had just come to town. Perhaps he could bring up the needle. Word of what had happened to the woman spread through the town and a great crowd of curious people gathered on the shore to see what would happen. In plain sight of all, by the use of his fingers and a long forceps, the doctor succeeded in producing the needle. Their own doctors had plainly failed. And the foreign doctor had just as plainly succeeded. The people were pleased. And the party of foreigners decided that after all they would not turn back.

When they arrived at Chang-te, their destination, they found the people more curious than hostile. As soon as their boat was tied up next to the shore, hundreds of people came to get their first glimpse of such strange-looking human beings. The doctor went ashore and was followed by people wherever he went. During his absence, the crowd at the boat became so great that the doors were pushed in and the roof was torn away by the more ill-mannered ones who insisted on an immediate personal inspection of the newcomers, their clothes, boxes, etc. The curiosity of the crowd was satisfied in part when the only woman in the party stepped outside so that all could see what a foreign woman looked like. The less timid Chinese women felt of her shoes and clothes, looked her up and down, front and back. It must have been an experience.

They rented a Chinese house in which to live and work. At first their living-rooms, the schoolroom, the dispensary and hospital, and the chapel were all in one

building. And this a building whose front door opened into the street and whose brick walls held neighbors immediately on the other side. In the back was a small yard to which the annual flood-water came dangerously near. Once the doctor rowed to a neighboring house, also outside the city, and found that in the first floor was six feet of water. In his own house the doctor was annoyed by rats. They were both numerous and daring. He did not mind it much so long as they confined themselves to running around the rooms and over the beds at night. But it was the limit of his patience when, on one occasion while trying to operate on a man who had tried to commit suicide by cutting his throat, he found that a venturesome old rat was walking around on the table he had reserved for his surgical instruments.

Despite crowded quarters and only the simplest of equipments this doctor "succeeded nevertheless." A man from another province was brought in because he was blind. The lenses of both eyes were opaque and had to be removed. Seeing, he returned to his home, but came back again after five months, bringing with him five friends blind, or nearly so, from different sorts of eye trouble. They had traveled a hundred miles to the hospital, and, headed by the man whose sight had been restored, they walked into the doctor's room, lock-step fashion, every man behind having his hand on the shoulder of the man next in front of him.

He operated on the eyes of an old woman beggar. The day she left the hospital she tried to express her appreciation by the promise to bring all the money she could beg into the hospitals so that other poor blind people

might be given back their sight. Poor patients out of gratitude often brought a chicken as a present. And in many cases a single chicken represents several days' wages for hard work.

After several thousand years the Chinese system of medicine is still a matter of giving tiger's teeth or something often equally ludicrous, and surgery a matter of letting out little devils of pain by puncturing the sick patient with long, dirty needles, bleeding, or some such method. From now on, however, this will become decreasingly true. Medical schools are being established along Western lines, and the influence of the Government is leaning very largely toward the new order of things.

In the very beginning of his work, "Doctor Succeeded Nevertheless" faced a unique difficulty. He wanted to build a hospital. But none of the Chinese builders in the city knew what a foreign hospital building should look like. Could they build him a house? They did not know what a foreign-built house ought to look like, either. There were no foreign buildings in the entire province. But there was one builder who had traveled more than his neighbors, and he remembered having seen a foreigner's house once, and that twelve years previously. Logs from up-country were hauled from the river into the compound, sawed up into lumber by the laborious process of two men and a hand rip-saw, and dressed for use. Everything had to be explained in detail again and again. This took months, but the hospital was finally completed and ready for use in 1902.

Late in the summer of 1912, Dr. Logan was returning

to Chang-te from the annual mission meeting, when the captain of the boat came into the cabin in great alarm with the news that cholera had broken out on the ship and that the first man to be stricken was his first officer. It was a Japanese river steamer, Siang Kiang Maru, with three hundred passengers who were already in a state of panic. They were still eight hours from their destination, with no intervening cities at which they might stop. Cholera spreads very rapidly, and, once taken with it, the stricken ones die within a few hours.

One glance at the sick man confirmed the captain's diagnosis. The doctor had not come prepared to do the unexpected. But he had a pocket case. From another passenger he borrowed a fountain-pen filler. On board the ship they discovered some rubber tubing and a funnel. From the dining-saloon table they obtained salt.

The cholera patient was isolated. Every precaution was taken to prevent others from becoming infected. With the table salt and boiled water a "normal salt solution" was made. The fountain-pen filler was inserted between two ends of rubber tubing to detect air bubbles. Connection was made between the funnel and a hypodermic needle. The saline injection outfit was complete.

By this time the first officer's face was blanched. His finger tips had that "washerwoman's hands" appearance which is characteristic of the last stages of the disease. His heart was fluttering and it was plain that death was not far off.

Carefully but speedily the vein at the elbow was laid bare with a sterilized pocket knife. After making sure

that there were no air bubbles anywhere, the hypodermic needle was driven into the exposed vein and the solution allowed to flow in at a little above normal body temperature. Several pints of the solution flowed into the man's veins, and thus into the general circulation. The officer's heart, from rapid, forceless flutterings, began to beat more slowly and steadily. His blanched features took on a more lifelike appearance. By and by a pulsing thread of flowing blood could be felt at the wrist. The finger tips filled out. The face showed returning color.

Before the operation the man was unconscious. After the injection he showed signs of life by moaning and trying to speak. The first thing he said was, "Give me a drink." On opening his eyes he recognized the captain standing at his side. After two weeks in the Chang-te hospital the officer was taken back to his ship, weak but out of danger.

Scarcely had the doctor unpacked his trunk after his return to Chang-te when there began to come in alarming reports of cholera outbreaks in all parts of the city. Every year there had been sporadic cases of cholera, but no epidemic had visited the city for twelve years. At that time there had been a loss of life which totaled many thousands. The doctor and his wife had lived through that epidemic and now they knew what to do.

The twenty-five men and women who helped him in the hospital were called together. It was a rather silent meeting. As he looked into their faithful but frightened faces the doctor saw those who were the only support of large families. He did not need to tell them what they

were facing. They knew. So he made it plain to them that not a single person was bound to stay. Not one left. And they went into the greatest fight of their lives.

Within a week cholera was raging in the city. And it was very plainly to be seen that it would be a physical impossibility to care for all the people once they became sick. Their hope lay in keeping the people from "catching" cholera. It was prevention rather than cure.

Copy was hastily prepared for ten thousand handbills. Before the ink was fairly dry these were being distributed everywhere in the city — on the streets, in the tea-shops, and in the public market-places. Bills were posted at all the city gates, and on those bulletin boards which so often serve the Chinese as newspapers.

A Chinese version of an American "sandwich man" was rigged up, to the astonishment of the natives. With his loud gong he attracted the attention of many to his signboard. When a crowd gathered he would shout out his warning at the top of his voice for those who were unable to read. At night an illuminated sign was carried through the streets. Two former patients were instructed what to say and then sent out to warn the people. The newspapers were used, also. Within a few days, by the use of all these methods, the news of how to prevent cholera spread pretty generally throughout the city.

Thousands obeyed the rules of prevention and lived. Hundreds scoffed at them and died. For the question as to what course to take was left entirely to the judgment of the individual citizen himself. There was no

municipal health department to say to the citizen, "This you must do, this you must not do, in order to protect yourself and the community."

At the main hospital entrance was this sign, "Only cholera patients admitted," and they came, rather they were brought, by the score. At times those who brought them blocked up the street with sedan chairs and improvised stretchers of bamboo poles. They were treated as they came, rich and poor alike. In the democracy of suffering the rich man lay helpless on a table adjoining that of a coolie in rags. When all the available space in the hospital was filled up, the out-patient dispensary room had to be turned into an operating-room. Seven operating-tables were constructed of rough boards and arranged conveniently in the large room. For every table there was a saline-solution stand with holders for the flasks. After being operated upon, only the worst cases could be allowed to remain, and all the others had to be sent back the way they came. In this way the great majority were given the saline treatment, were sent back within a few hours, and their places were given to newcomers.

The very success of the treatment brought new difficulties. What one hundred and twenty-five bed hospital in America could accommodate fifty intravenous injections of several pints each in one day for many days in succession without the least warning? And what if this American hospital could not replenish the equipment short of three weeks? And yet, during this epidemic in Chang-te, as many as sixty-one patients were operated upon in one day. Some days the staff worked

twenty hours out of the twenty-four. There were no other doctors or nurses within hundreds of miles, and no connecting railroad if there had been.

When the stock of rubber tubing ran short and spoiled from repeated sterilization, the stomach pumps in the hospital were cut up, and all foreigners in the city who had rubber tubing of any sort were asked to contribute. In the hospital there were only two nozzles such as are regularly used for intravenous work. So small glass medicine droppers had to be used instead. Everybody contributed ideas or material.

One of the most serious difficulties was met successfully by one of the menial hospital coolies. Since every patient had to have from one pint to several quarts of distilled water with salt in it, the water could not be distilled fast enough. For two days the staff struggled along with makeshifts while thinking up a plan to build a still for little money without the loss of time. This coolie solved the problem. In one day and at a cost of less than two dollars he built a still which later produced twenty gallons of distilled water every twenty-four hours.

The still was simplicity itself. For cooking food, the Chinese use large, flat, saucer-like pans made of iron. With one of these above and another below, the coolie made a drum of galvanized iron with a hole in the side for a trough. Into the lower pan hot water for boiling was poured. Underneath, a hot fire sent up a constant steam vapor. The upper kettle was kept cool by frequent changings of cold water. The vapor from the lower kettle, condensed on the lower surface of the cool

upper kettle, dripped off into the trough, and filled bottle after bottle with distilled water.

While "Doctor Succeeded Nevertheless" and his staff were working out the salvation of Chang-te, a group of foreign doctors and a still larger Chinese staff were fighting an epidemic of cholera in Shanghai. When the smoke of battle cleared away, or rather when the doctors hung up their operating-gowns after the scourge disappeared, it was found that two new world's records had been established in the combating of cholera. The world's record went to the doctors at Shanghai. The next closest record went to Dr. Logan and his staff, a thousand miles up-river.

In the Chang-te epidemic, six hundred and three patients had been given the "intravenous-injection-with-salt-solution" treatment. The amount of solution carried out of the hospital by these six hundred and three patients was a ton and a half. In a way, this is a world's record, in that never before were so many persons treated intravenously in so short a time and under such difficult circumstances. How many hundreds or thousands were saved by means of the campaign of prevention cannot, of course, be estimated. Not a member of the hospital staff became ill.

THE STORY OF A PRIMROSE

By Arabella B. Buckley

I ASK you to fix your attention on one little plant, and to inquire into its history.

There is a beautiful little poem by Tennyson, which says —

> "Flower in the crannied wall,
> I pluck you out of the crannies;
> Hold you here, root and all, in my hand,
> Little flower; but if I could understand
> What you are, root and all, and all in all,
> I should know what God and man is."

We cannot learn *all* about this little flower, but we can learn enough to understand that it has a real separate life of its own, well worth knowing. For a plant is born, breathes, sleeps, feeds, and digests just as truly as an animal does, though in a different way. It works hard both for itself to get its food, and for others in making the air pure and fit for animals to breathe. It often lays by provision for the winter. It sends young plants out, as parents send their children, to fight for themselves in the world; and then, after living sometimes to a good old age, it dies, and leaves its place to others.

We will try to follow out something of this life to-day; and first, we will begin with the seed.

I have here a packet of primrose seeds, but they are so small that we cannot examine them; so I have also had given to each one of you an almond kernel, which is

the seed of the almond tree, and which has been soaked, so that it splits in half easily. From this we can learn about seeds in general, and then apply it to the primrose.

If you peel the two skins off your almond seed (the thick, brown, outside skin, and the thin, transparent one under it), the two halves of the almond will slip apart quite easily. One of these halves will have a small dent at the pointed end, while in the other half you will see a little lump, which fitted into the dent when the two halves were joined. This little lump is a young plant, and the two halves of the almond are the seed leaves which hold the plantlet, and feed it till it can feed itself. The rounded end of the plantlet sticking out of the almond, is the beginning of the root, while the other end will in time become the stem. If you look carefully, you will see two little points at this end, which are the tips of future leaves. Only think how minute this plantlet must be in a primrose, where the whole seed is scarcely larger than a grain of sand! Yet in this tiny plantlet lies hid the life of the future plant.

When a seed falls into the ground, so long as the earth is cold and dry, it lies like a person in a trance, as if it were dead; but as soon as the warm, damp spring comes, and the busy little sun waves pierce down into the earth, they wake up the plantlet, and make it bestir itself. They agitate to and fro the particles of matter in this tiny body, and cause them to seek for other particles to seize and join to themselves.

But these new particles cannot come in at the roots, for the seed has none; nor through the leaves, for they

have not yet grown up; and so the plantlet begins by helping itself to the store of food laid up in the thick seed-leaves in which it is buried. Here it finds starch, oils, sugar, and substances called "albuminoids" — the sticky matter which you notice in wheat grains when you chew them is one of the albuminoids. This food is all ready for the plantlet to use, and it sucks it in, and works itself into a strong plant with tiny roots at one end, and a growing shoot, with leaves, at the other.

But how does it grow? What makes it become larger? To answer this, you must look at the second thing I asked you to bring — a piece of orange. If you take the skin off a piece of orange, you will see inside a number of long, tapering, transparent bags, full of juice. These we call "cells," and the flesh of all plants and animals is made up of cells like these, only of various shapes. In the pith of elder they are round, large, and easily seen; in the stalks of plants they are long, and lap over each other, so as to give the stalk strength to stand upright. Sometimes many cells, growing one on the top of the other, break into one tube and make "vessels." But whether large or small, they are all bags growing one against the other.

In the orange pulp these cells contain only sweet juice, but in other parts of the orange tree or any other plant they contain a sticky substance with little grains in it. This substance is called "protoplasm," or the *first form* of life, for it is alive and active, and under a microscope you may see in a living plant streams of the little grains moving about in the cells.

Now we are prepared to explain how our plant grows. Imagine the tiny primrose plantlet to be made up of cells filled with active living protoplasm, which drinks in starch and other food from the seed leaves. In this way each cell will grow too full for its skin, and then the protoplasm divides into two parts and builds up a wall between them, and so one cell becomes two. Each of these two cells again breaks up into two more, and so the plant grows larger and larger, till by the time it has used up all the food in the seed leaves, it has sent roots covered with fine hairs downwards into the earth, and a shoot with beginnings of leaves up into the air.

Sometimes the seed leaves themselves come above ground, as in the mustard plant, and sometimes they are left empty behind, while the plantlet shoots through them.

And now the plant can no longer afford to be idle and live on prepared food. It must work for itself. Until now it has been taking in the same kind of food that you and I do; for we too find many seeds very pleasant to eat and useful to nourish us. But now this store is exhausted. Upon what then is the plant to live? It is cleverer than we are in this, for while we cannot live unless we have food which has once been alive, plants can feed upon gases and water and mineral matter only. Think over the substances you can eat or drink, and you will find they are nearly all made of things which have been alive: meat, vegetables, bread, milk; all these are made from living matter, and though you do take in such things as water and salt, and even iron and phosphorus, these would be quite useless if you did not eat

and drink prepared food which your body can work up into living matter.

But the plant, as soon as it has roots and leaves, begins to make living matter out of matter that has never been alive. Through all the little hairs of its roots it sucks in water, and in this water are dissolved more or less of the salts of ammonia, phosphorus, sulphur, iron, lime, magnesia, and even silica, or flint. In all kinds of earth there is some iron, and we shall see presently that this is very important to the plant.

Suppose, then, that our primrose has begun to drink in water at its roots. How is it to get this water up into the stem and leaves, seeing that the whole plant is made of closed bags or cells? It does it in a very curious way, which you can prove for yourselves. Whenever two fluids, one thicker than the other, such as molasses and water, for example, are only separated by a skin or any porous substance, they will always mix, the thinner one oozing through the skin into the thicker one. If you tie a piece of bladder over a glass tube, fill the tube half-full of molasses, and then let the covered end rest in a bottle of water, in a few hours the water will get in to the molasses and the mixture will rise up in the tube till it flows over the top. Now, the saps and juices of plants are thicker than water, so, as soon as the water enters the cells at the root it oozes up into the cells above, and mixes with the sap. Then the matter in those cells becomes thinner than in the cells above, so it too oozes up, and in this way cell by cell the water is pumped up into the leaves.

When it gets there, it finds the sunbeams hard at work.

If you have ever tried to grow a plant in a cellar, you will know that in the dark its leaves remain white and sickly. It is only in the sunlight that a beautiful delicate green tint is given to them, and you will remember that this green tint shows that the leaf has used all the sun waves except those which make you see green; but why should it do this only when it has grown up in the sunshine?

The reason is this: when the sunbeam darts into the leaf and sets all its particles quivering, it divides the protoplasm into two kinds, collected into different cells. One of these remains white, but the other kind, near the surface, is altered by the sunlight and by the help of the iron brought in by the water. This particular kind of protoplasm, which is called "chlorophyll," will have nothing to do with the green waves and throws them back, so that every little grain of this protoplasm looks green and gives the leaf its green color.

It is these little green cells that by the help of the sun waves digest the food of the plant and turn the water and gases into useful sap and juices. We saw in a previous lecture that when we breathe in air, we use up the oxygen in it and send back out of our mouths carbonic acid, which is a gas made of oxygen and carbon.

Now, every living thing wants carbon to feed upon, but plants cannot take it by itself, because carbon is solid (the "lead" in your pencils is pure carbon), and a plant cannot *eat,* it can only drink in fluids and gases. Here the little green cells help it out of its difficulty. They take in or *absorb* out of the air the carbonic acid gas which we have given out of our mouths, and then

by the help of the sun waves they tear the carbon and oxygen apart. Most of the oxygen they throw back into the air for us to use, but the carbon they keep.

If you will take some fresh laurel leaves and put them into a tumbler of water turned upside down in a saucer of water, and set the tumbler in the sunshine, you will soon see little bright bubbles rising up and clinging to the glass. These are bubbles of oxygen gas, and they tell you that they have been set free by the green cells which have torn from them the carbon of the carbonic acid in the water.

But what becomes of the carbon? And what use is made of the water which we have kept waiting all this time in the leaves? Water, you already know, is made of hydrogen and oxygen; but perhaps you will be surprised when I tell you that starch, sugar, and oil, which we get from plants, are nothing more than hydrogen and oxygen in different quantities joined to carbon.

It is difficult to picture such a black thing as carbon making part of delicate leaves and beautiful flowers, and still more of pure white sugar. But we can make an experiment by which we can draw the hydrogen and oxygen out of common loaf sugar, and then you will see the carbon stand out in all its blackness. I have here a plate with a heap of white sugar in it. I pour upon it first some hot water to melt and warm it, and then some strong sulphuric acid. This acid does nothing more than simply draw the hydrogen and oxygen out. See! in a few moments a black mass of carbon begins to rise, all of which has come out of the white sugar you saw just now. You see, then, that from the whitest substance in

plants we can get this black carbon; and in truth, one half of the dry part of every plant is composed of it.

Now look at my plant again, and tell me if we have not already found a curious history? Fancy that you see the water creeping in at the roots, oozing up from cell to cell till it reaches the leaves, and there meeting the carbon which has just come out of the air, and being worked up with it by the sun waves into starch, or sugar, or oils.

But meanwhile, how is new protoplasm to be formed? for without this active substance none of the work can go on. Here comes into use the lazy gas called nitrogen, which we spoke of in a previous lecture. There we thought that nitrogen was of no use except to float oxygen in the air, but here we shall find it very useful. So far as we know, plants cannot take up nitrogen out of the air, but they can get it out of the ammonia which the water brings in at their roots.

Ammonia, you will remember, is a strong-smelling gas, made of hydrogen and nitrogen. The plant gets some from the soil and also from the rain-drops which bring it down in the air. Out of this ammonia the plant takes the nitrogen and works it up with the three elements, carbon, oxygen, and hydrogen, to make the substances called albuminoids, which form a large part of the food of the plant, and it is these albuminoids which go to make protoplasm. You will notice that while the starch and other substances are made of three elements only, the active protoplasm is made of these three added to a fourth, nitrogen, and it also contains phosphorus and sulphur.

And so hour after hour and day after day our primrose goes on pumping up water and ammonia from its roots to its leaves, drinking in carbonic acid from the air, and using the sun waves to work them all up into food to be sent to all parts of its body. In this way these leaves act as the stomach of the plant, and digest its food.

Sometimes more water is drawn up into the leaves than can be used, and then the leaf opens thousands of little mouths in the skin of its under surface, which let the drops out just as drops of perspiration ooze through our skin when we are overheated. These little mouths, which are called "stomates," are made of two flattened cells, fitting against each other. When the air is damp and the plant has too much water these lie open and let it out, but when the air is dry and the plant wants to keep as much water as it can, then they are closely shut. There are as many as a hundred thousand of these mouths under one apple leaf, so you may imagine how small they often are.

Plants which live only one year, such as mignonette, the sweet pea, and the poppy, take in just enough food to supply their daily wants and to make their seeds. Then, as soon as the seeds are ripe their roots begin to shrivel, and water is no longer carried up. The green cells can no longer get food to digest, and they themselves are broken up by the sunbeams and turn yellow, and the plant dies.

But many plants are more industrious than the stock and mignonette, and lay by store for another year, and our primrose is one of these. Look at this thick solid

mass below the primrose leaves, out of which the roots spring. This is really the stem of the primrose hidden underground, and all the starch, albuminoids, etc., which the plant can spare as it grows, are sent down into this underground stem and stored up there, to lie quietly in the ground through the long winter, and then when the warm spring comes, this stem begins to send out leaves for a new plant.

THE STORY OF THE FRACTIONS

By Grace Tabor

"ONE and one are two, and one are three, and one are four, and one are —"

"Multiplying would be much quicker."

"And one are five, and one are six, and one —"

"Why don't you multiply instead of add?"

"Are seven, and one are eight, and —"

"What in the world are you thinking of? Don't you know — ?"

"That it is very poor manners to interrupt? *Yes!* And very poor taste to advise, to say nothing of showing you up, when you do not know a thing about the situation or the problem? Yes! But it would seem that I am singularly alone in the possession of this knowledge — as well as some other!"

The tone was more than snappy, but there was no denying the provocation was great. The questioner was entirely unabashed, however. Indeed, he promptly asked the question over again: "Well, why *don't* you multiply?"

"Because I must have more when I finish than when I began, and because it's fractions I am using. And if I *multiply* fractions, I'll get less instead of more, won't I, Mr. Know-it-all?"

"Oh, well, of course!" said the other, with the in-

flection that is always used when one says this; and he withdrew without more ado, rather pettishly, one might say.

And the sum went on; and the number of the fractions increased; and the fractions themselves increased; and so it was that finally, when the summer was over, where there had been just one honeysuckle vine clambering over the fence, were ever and ever so many rooted bits or fractions of a vine that were already beginning to send up shoots that twined their way up toward the sky and took on all the airs and attributes of vines themselves. And these the two garden sages together cut away and planted all the way along the rough old fence, perhaps three feet apart; and thus all its long unsightliness was covered with a lovely fragrant mass of this loveliest of vines, when the next summer came — a mass that was the beginning of a famous honeysuckle hedge. For there it grew and grew, and went on layering itself season after season, until it became an impenetrable tangle of crisscrossed branches quite four feet thick, all built up by the addition of the fractions of the first vine that had itself been a fraction of a grandmother's honeysuckle, quite a long way from the home of the small sage.

Some plants take to this method of increase by fraction-addition much more readily than others — perhaps they are naturally of a mathematical turn of mind! — and there are very few that cannot be persuaded to it, through proper attention and coaxing. Upon it, therefore, gardeners great and small have learned to rely for many things, rather than upon the slower method of

raising plants from seeds. Propagating by cuttings or by layers they call it.

Honeysuckle is one of the things that layer themselves; that is, its branches take root wherever they touch the ground. Mint creeps along and spreads itself over large spaces in the same way; so does the sweet trailing arbutus, and the shining-leaved but pernicious poison-ivy. Grapes often do, blackberries always do; strawberries travel along in this way, new plants forming continually around the old; tomatoes will do it; the hobble-bush, which may have thrown you flat as you were running in the woods sometime, owes its name (and you owe your tumble) to this habit, for its branches fasten themselves by roots to the earth again and again as they grow long enough to touch it, and thus they form into low-stretched snares to trip the unwary.

Here is an odd thing about new plants produced from an old one in this way which it is interesting to note and remember. Such plants are just as old in one way as the original one, even if that is years and years old and they are but just separated from it. So there is no waiting for them to grow up and blossom, if they are shrubs; for already they are old enough, and will blossom, the very first year of their independent life, even though they are no larger in height and size generally than year-old seedling baby plants. They are in gardening language, "precocious"; and very often it is nice to have shrubs and trees precocious, so that we may enjoy them from the very beginning of their residence with us.

This is not the only reason for increasing shrubs and plants in this way, however, although it is an important

one. But there are some things which will not "run true," as gardeners put it, from seed; which is a very great puzzle, and no one knows just why it is so, although they know very well that it is. It means that the seeds of a flower will not always give us plants which will, in their turn, bear flowers exactly like the one from which these seeds came. Consequently, when we wish to have more plants that will bear this particular kind of flower, we may only do so by propagating, or making the new plants out of fractions or cuttings of the original plant, instead of raising them from its seeds. Thus we are able to have exactly the same wood and stem, and therefore exactly the same flower. So for certainty in handling some plants, more especially the finer and more highly developed varieties, propagating by layers or cuttings is really the only method.

Layers, you will already have gathered, are just what their name implies — long branches that lie along the ground and send roots out at intervals down into it. And cuttings are as true to their name as layers, for they are the fractions which are subtracted from the main plant before their roots have formed — cut off and separated — and then set into the ground by way of inviting them to take root. Of course you will not be slow to guess that these are much more difficult to make grow, in one way, because they must do all the work of making roots alone and unaided; whereas layers have it done for them, and moisture and nourishment furnished to them by the roots of the plant of which they remain a part until these new roots are formed, and are quite prepared to take up existence as separate, new, and independent plants.

Gardeners have learned to employ four different kinds of layering, all amounting to the same thing, of course, yet varying a little bit. All depend upon the same two principles, that is, that roots like darkness, and that an interrupted flow of sap in a branch tends to make that branch put forth new roots to restore this flow to its normal volume and thus restore to the plant its normal amount of nourishment. When a plant is growing above-ground, buds and branches rise out of the stem at certain definite places along its length. These places are called "nodes"; and the spaces between them are called the "joints" of the stem. When a stem is covered with earth, it is at these nodes that roots are more likely to arise than elsewhere along the stem. It is to them, therefore, that our attention must be given, in a general way.

To layer a thing in the simplest fashion, choose a long branch of last summer's growth, — unless you are specially directed to take younger shoots, remember that nicely ripened, *woody* wood a year old is always to be chosen, — and after hollowing a shallow trench in the earth from the base of the shrub out toward its circumference, like the spoke of a wheel, as long as this branch, draw it over and down carefully. Work very slowly with it to be sure it bends without splintering, gradually getting it all the way down until it lies along this trench from its tip to as near the plant itself as it can safely be bent. Lay a good-sized stone on it to hold it in place, once you get it just right, for the weight of the earth which will go over it is seldom enough to overcome its natural spring back to an upright position.

This bending down interrupts the flow of sap. Now, to provide the darkness, over two or three adjoining joints or nodes of the branch pull the earth back into place, covering leaves and stem and all to a depth of three or four inches, quite out of sight. Then skip and leave uncovered about two nodes, and cover the next two or three; and so on, the whole length of the stem. This leaves a space along the stem, you see, between each portion that is in the dark and going to send roots down, for branches to grow up, above the ground.

After these little branches or shoots have grown to be two or three inches high, cover the earth over the rest of the main branch and around them, until they look like a row of little separate plants standing there — and then leave everything alone for a long, long time, that Nature may do her work.

Just how long a time depends on two things — the plant, and the season of the year when the work is done. Some plants naturally take root much more quickly than others; and all plants take root more promptly if layered at the time of their greatest activity, which is always spring or early summer. Usually the little plants are ready to cut away by the time fall comes, if the layers are laid down in the spring; but with some things, even this is too soon, and we must wait over until the next spring, or even the next fall. Such a long time is not usual, however.

All of this that has just been described is called simple layering; and it is the easiest and best for all ordinary circumstances and plants.

BEES AND FLOWERS

By Arabella B. Buckley

FANCY yourself to be in a pretty country garden on a hot summer's morning. Perhaps you have been walking, or reading, or playing, but it is getting too hot now to do anything; and so you have chosen the shadiest nook under the old walnut tree, close to the flower-bed on the lawn, and would almost like to go to sleep if it were not too early in the day.

As you lie there thinking of nothing in particular, except how pleasant it is to be idle now and then, you notice a gentle buzzing close to you, and you see that on the flower-bed close by, several bees are working busily among the flowers. They do not seem to mind the heat, nor to wish to rest; and they fly so lightly and look so happy over their work that it does not tire you to look at them.

That great humblebee takes it leisurely enough as she goes lumbering along, poking her head into the larkspurs, and remaining so long in each you might almost think she had fallen asleep. The brown hive bee, on the other hand, moves busily and quickly among the stocks, sweet peas, and mignonette. She is evidently out on active duty, and means to get all she can from each flower, so as to carry a good load back to the hive. In some blossoms she does not stay a moment, but draws her head back as soon as she has popped it in, as if to

say, "No honey there." But over the full blossoms she lingers a little, and then scrambles out again with her drop of honey, and goes off to seek more in the next flower.

Let us watch her a little more closely. There are plenty of different plants growing in the flower-bed, but, curiously enough, she does not go first to one kind and then to another; but keeps to one, perhaps the mignonette, the whole time, till she flies away. Rouse yourself up to follow her, and you will see she takes her way back to the hive. She may perhaps stop to visit a stray plant of mignonette on her way, but no other flower will tempt her till she has taken her load home.

Then when she comes back again she may perhaps go to another kind of flower, such as the sweet peas, for instance, and keep to them during the next journey, but it is more likely that she will be true to her old friend the mignonette for the whole day.

We all know why she makes so many journeys between the garden and the hive, and that she is collecting drops of honey from each flower, and carrying it to be stored up in the honeycomb for winter's food. Now we will follow her in her work among the flowers, and see, while they are so useful to her, what she is doing for them in return.

We have learned that plants can make better and stronger seeds when they can get pollen dust from another plant, than when they are obliged to use that which grows in the same flower; but I am sure you will be very much surprised to hear that the more we study flowers the more we find that their colors, their scent,

and their curious shapes are all so many baits and traps set by Nature to entice insects to come to the flowers, and carry this pollen dust from one to another.

So far as we know, it is entirely for this purpose that the plants form honey in different parts of the flower, sometimes in little bags or glands, as in the petals of the buttercup flower, sometimes in clear drops, as in the tube of the honeysuckle. This food they prepare for the insects, and then they have all sorts of contrivances to entice them to come and fetch it.

You will remember that the plants of the coal had no bright or conspicuous flowers. Now we can understand why this was, for there were no flying insects at that time to carry the pollen dust from flower to flower, and therefore there was no need of colored flowers to attract them. But little by little, as flies, butterflies, moths and bees began to live in the world, flowers too began to appear, and plants hung out these gay-colored signs, as much as to say, "Come to me, and I will give you honey if you will bring me pollen dust in exchange, so that my seeds may grow healthy and strong."

We cannot stop to inquire to-day how this all gradually came about, and how the flowers gradually put on gay colors and curious shapes to tempt the insects to visit them; but we will learn something about the way they attract them now, and how you may see it for yourselves if you keep your eyes open.

For example, if you watch the different kinds of grasses, sedges, and rushes, which have such tiny flowers that you can scarcely see them, you will find that no insects visit them. Neither will you ever find bees buzz-

ing round oak trees, nut trees, willows, elms, or birches. But on the pretty and sweet-smelling apple blossoms, or the strongly scented lime-trees, you will find bees, wasps, and plenty of other insects.

The reason of this is that grasses, sedges, rushes, nut trees, willows, and the others we have mentioned, have all of them a great deal of pollen dust, and as the wind blows them to and fro, it wafts the dust from one flower to another, and so these plants do not want the insects, and it is not worth their while to give out honey, or to have gaudy or sweet-scented flowers to attract them.

But wherever you see bright or conspicuous flowers you may be quite sure that the plants want the bees or some other winged insect to come and carry their pollen for them. Snowdrops hanging their white heads among their green leaves, crocuses with their violet and yellow flowers, the gaudy poppy, the large-flowered hollyhock or the sunflower, the flaunting dandelion, the pretty pink willow herb, the clustered blossoms of the mustard and turnip flowers, the bright blue forget-me-not and the delicate little yellow trefoil, all these are visited by insects, which easily catch sight of them as they pass by and hasten to sip their honey.

Sir John Lubbock has shown that bees are not only attracted by bright colors, but that they even know one color from another. He put some honey on slips of glass with colored papers under them, and when he had accustomed the bees to find the honey always on the blue glass, he washed this glass clean, and put the honey on the red glass instead. Now if the bees had followed only the smell of the honey, they would have flown to the

red glass, but they did not. They went first to the blue glass, expecting to find the honey on the usual color, and it was only when they were disappointed that they went off to the red.

Neither must we forget what sweet scents can do. Have you never noticed the delicious smell which comes from beds of mignonette, thyme, rosemary, mint, or sweet alyssum, from the small hidden bunches of laurustinus blossom, or from the tiny flowers of the privet? These plants have found another way of attracting the insects; they have no need of bright colors, for their scent is quite as true and certain a guide. You will be surprised if you once begin to count them up, how many white and dull or dark-looking flowers are sweet-scented, while gaudy flowers, such as the tulip, foxglove, and hollyhock, have little or no scent. And then we find some flowers, like the beautiful lily, the lovely rose, and the delicate hyacinth, which have color and scent and graceful shapes all combined.

But we are not yet nearly at an end of the contrivances of flowers to secure the visits of insects. Have you not observed that different flowers open and close at different times? The daisy received its name "day's eye," because it opens at sunrise and closes at sunset, while the evening primrose and the night campion spread out their flowers just as the daisy is going to bed.

What do you think is the reason of this? If you go near a bed of evening primroses just when the sun is setting, you will soon be able to guess, for they will then give out such a sweet scent that you will not doubt for a moment that they are calling the evening moths to come

and visit them. The daisy opens by day because it is visited by day insects, but those particular moths which can carry the pollen dust of the evening primrose, fly only by night, and if this flower opened by day other insects might steal its honey, while they would not be the right size or shape to touch its pollen bags and carry the dust.

It is the same if you pass by a honeysuckle in the evening; you will be surprised to find how much stronger its scent is than in the daytime. This is because the sphinx hawk moth is the favorite visitor of that flower, and comes at nightfall, guided by the strong scent, to suck out the honey with its long proboscis, and carry the pollen dust.

Again, some flowers close whenever rain is coming. The pimpernel is one of these, hence its name of the "shepherd's weather-glass." This little flower closes, no doubt, to prevent its pollen dust being washed away, for it has no honey; while other flowers do it to protect the drop of honey at the bottom of their corolla. Look at the daisies for example when a storm is coming on; as the sky grows dark and heavy, you will see them shrink up and close till the sun shines again. They do this because in each of the little yellow florets in the center of the flower there is a drop of honey which would be quite spoiled if it were washed by the rain.

And now you will see why cup-shaped flowers so often droop their heads — think of the harebell, the snowdrop, the lily-of-the-valley, the campanula, and a host of others; how pretty they look with their bells hanging so modestly from the slender stalk! They are bending down to protect the honey glands within them, for if

the cup became full of rain or dew the honey would be useless, and the insects would cease to visit them.

But it is not only necessary that the flowers should keep their honey for the insects, they also have to take care and keep it for the right kind of insect. Ants are in many cases great enemies to them, for they like honey as much as bees and butterflies do, yet you will easily see that they are so small that if they creep into a flower they pass the anthers without doing any good to the plant. Therefore we find numberless contrivances for keeping the ants and other creeping insects away. Look for example at the hairy stalk of the primrose flower; those little hairs are like a forest to a tiny ant, and they protect the flower from his visits. The Spanish catchfly, on the other hand, has a smooth but very gummy stem, and on this the insects stick, if they try to climb. Slugs and snails too will often attack and bite flowers, unless they are kept away by thorns and bristles, such as we find on the teazel and the burdock. And so we are gradually learning that everything which a plant does has its meaning, if we can only find it out, and that even every insignificant hair has its own proper use, and when we are once aware of this a flower-garden may become quite a new world to us if we open our eyes to all that is going on in it.

But as we cannot wander among many plants to-day, let us take a few which the bees visit, and see how they contrive not to give up their honey without getting help in return. We will start with the blue wood-geranium, because from it we first began to learn the use of insects to flowers.

More than a hundred years ago a young German botanist, Christian Conrad Sprengel, noticed some soft hairs growing in the center of this flower, just round the stamens, and he was so sure that every part of a plant is useful, that he set himself to find out what these hairs meant. He soon discovered that they protected some small honey bags at the base of the stamens, and kept the rain from washing the honey away, just as our eyebrows prevent the perspiration on our faces from running into our eyes. This led him to notice that plants take great care to keep their honey for insects, and by degrees he proved that they did this in order to tempt the insects to visit them and carry off their pollen.

The first thing to notice in this little geranium flower is that the purple lines which ornament it all point directly to the place where the honey lies at the bottom of the stamens, and actually serve to lead the bee to the honey; and this is true of the veins and markings of nearly all flowers except of those which open by night, *and in these they would be useless, for the insects would not see them.*

When the geranium first opens, all its ten stamens are lying flat on the corolla or colored crown, and then the bee cannot get at the honey. But in a short time five stamens begin to raise themselves and cling round the stigma or knob at the top of the seed vessel. Now you would think they would leave their dust there. But no! the stigma is closed up so tight that the dust cannot get on to the sticky part. Now, however, the bee can get at the honey glands on the outside of the raised stamens; and as he sucks it, his back touches the anthers or dust

bags, and he carries off the pollen. Then, as soon as all their dust is gone, these five stamens fall down, and the other five spring up. Still, however, the stigma remains closed, and the pollen of these stamens, too, may be carried away to another flower. At last these five also fall down, and then, and not till then, the stigma opens and lays out its five sticky points.

But its own pollen is all gone; how then will it get any? It will get it from some bee who has just taken it from another and younger flower; and thus you see the blossom is prevented from using its own pollen, and made to use that of another blossom, so that its seeds may grow healthy and strong.

The garden nasturtium, into whose blossom we saw the humblebee poking his head, takes still more care of its pollen dust. It hides its honey down at the end of its long spur, and only sends out one stamen at a time, instead of five like the geranium; and then, when all the stamens have had their turn, the sticky knob comes out last for pollen from another flower.

All this you may see for yourselves if you find geraniums in the fields and nasturtiums in your garden. But even if you have not these, you may learn the history of another flower quite as curious, and which you can find in any field or lane. The common dead nettle takes a great deal of trouble in order that the bee may carry off its pollen. When you have found one of these plants, take a flower from the ring all round the stalk and tear it gently open, so that you can see down its throat. There, just at the very bottom, you will find a thick fringe of hairs, and you will guess at once that these are

to protect a drop of honey below. Little insects which would creep into the flower and rob it of its honey without touching the anthers of the stamens cannot get past these hairs, and so the drop is kept till the bee comes to fetch it.

Now look for the stamens: there are four of them, two long and two short, and they are quite hidden under the hood which forms the top of the flower. How will the bee touch them? If you were to watch one, you would find that when the bee alights on the broad lip, and thrusts her head down the tube, she first of all knocks her back against the little forked tip. This is the sticky stigma, and she leaves there any dust she has brought from another flower; then, as she must push far in to reach the honey, she rubs the top of her back against the anthers, and before she comes out again has carried away the yellow powder on her back, ready to give it to the next flower.

Do you remember how we noticed at the beginning of the lecture that a bee always likes to visit the same kind of plant in one journey? You see now that this is very useful to the flowers. If the bee went from a dead nettle to a geranium, the dust would be lost, for it would be of no use to any other plant but a dead nettle. But since the bee likes to get the same kind of honey each journey, she goes to the same kind of flowers, and places the pollen dust just where it is wanted.

There is another flower called the "salvia," which belongs to the same family as the dead nettle, and I think you will agree with me that its way of dusting the bee's back is most clever. The salvia is shaped just like

the dead nettle, with a hood and a broad lip, but instead of four stamens it has only two, the other two being shriveled up. The two that are left have a very strange shape, for the stalk or filament of the stamen is very short, while the anther, which is in most flowers two little bags stuck together, has here grown out into a long thread, with a little dust bag at one end only. Now, when the bee puts her head into the tube to reach the honey, she passes right between these two swinging anthers, and knocking against the end pushes it before her and so brings the dust bag plump down on her back, scattering the dust there! You can easily try this by thrusting a pencil into any salvia flower, and you will see the anther fall.

You will notice that all this time the bee does not touch the sticky stigma which hangs high above her, but after the anthers are empty and shriveled the stalk of the stigma grows longer, and it falls lower down. By and by another bee, having pollen on her back, comes to look for honey, and as she goes into this flower, she rubs against the stigma and leaves upon it the dust from another flower.

The common sweet violet or the dog violet give up their pollen in quite a different way from the salvia, and yet it is equally ingenious. Every one has noticed what an irregular shape this flower has, and that one of its purple petals has a curious spur sticking out behind. In the tip of this spur and in the spur of the stamen lying in it the violet hides its honey, and to reach it the bee must press past the curious ring of orange-tipped bodies in the middle of the flower. These bodies are the

anthers, which fit tightly round the stigma, so that when the pollen dust, which is very dry, comes out of the bags, it remains shut in by the tips as if in a box. Two of these stamens have spurs which lie in the colored spur of the flower, and have honey at the end of them. Now, when the bee shakes the end of the stigma, it parts the ring of anthers, and the fine dust falls through upon the insect.

Let us see for a moment how wonderfully this flower is arranged to bring about the carrying of the pollen, as Sprengel pointed out years ago. In the first place, it hangs on a thin stalk, and bends its head down so that the rain cannot come near the honey in the spur, and also so that the pollen dust falls forward into the front of the little box made by the closed anthers. Then the pollen is quite dry, instead of being sticky as in most plants. This is in order that it may fall easily through the cracks. Then the style or stalk of the stigma is very thin and its tip very broad, so that it quivers easily when the bee touches it, and so shakes the anthers apart, while the anthers themselves fold over to make the box, and yet not so tightly but that the dust can fall through when they are shaken. Lastly, if you look at the veins of the flower, you will find that they all point toward the spur where the honey is to be found, so that when the sweet smell of the flower has brought the bee, she cannot fail to go in at the right place.

The bird's-foot trefoil is shaped very much like the flower of a pea, and indeed it belongs to the same family, called the butterfly family, because the flowers look something like an insect flying.

In all these flowers the top petal stands up like a flag

to catch the eye of the insect, and for this reason botanists call it the "standard." Below it are two side petals called the "wings," and if you pick these off you will find that the remaining two petals are joined together at the tip in a shape like the keel of a boat. For this reason they are called the "keel." Notice that these last two petals have in them a curious little hollow or depression, and if you look inside the "wings," you will notice a little knob that fits into this hollow, and so locks the two together. We shall see by-and-by that this is important.

Next let us look at the half-flower when it is cut open, and see what there is inside. There are ten stamens in all, enclosed with the stigma in the keel; nine are joined together and one is by itself. The anthers of five of these stamens burst open while the flower is still a bud, but the other stamens go on growing and push the pollen dust, which is very moist and sticky, up into the tip of the keel. It lies right round the stigma, but as we saw before in the geranium, the stigma is not ripe and sticky yet, and so it does not use the pollen grains.

Now suppose that a bee comes to the flower. The honey she has to fetch lies inside the tube, and the one stamen being loose she is able to get her proboscis in. But if she is to be of any use to the flower she must uncover the pollen dust. See how cunningly the flower has contrived this. In order to put her head into the tube, the bee must stand upon the wings, and her weight bends them down. But they are locked to the keel by the knob fitting into the hole, and so the keel is pushed down too, and the sticky pollen dust is uncovered and comes

right against the stomach of the bee and sticks there! As soon as she has done feeding and flies away, up go the wings and the keel with them, covering up any pollen that remains ready for next time. Then when the bee goes to another flower, as she touches the stigma as well as the pollen, she leaves some of the foreign dust upon it, and the flower uses that rather than its own, because it is better for its seeds. If, however, no bee happens to come to one of these flowers, after a time the stigma becomes sticky and it uses its own pollen: and this is perhaps one reason why the bird's-foot trefoil is so very common, because it can do its own work if the bee does not help it.

HOW FLOWERS CLUB TOGETHER

(*Abridged*)

By Grant Allen

VERY large flowers, like the water-lily, the tulip, the magnolia, the daffodil, are usually solitary; they suffice by themselves to attract in sufficient numbers the fertilizing insects. But smaller flowers often find it pays them better to group themselves into big spikes or masses, as one sees, for example, in the foxglove and the lilac. Such an arrangement makes the mass more conspicuous, and it also induces the insect, when he comes, to fertilize at a single visit a large number of distinct blossoms. It is a mutual convenience; for the bee or butterfly, it saves valuable time; for the plant, it ensures more prompt and certain fertilization. In many families, therefore, we can trace a regular gradation between large and almost solitary flowers, through smaller and somewhat clustered flowers, to very small and comparatively crowded flowers. Thus the largest lilies are usually solitary or grow at best three or four together, like the *lilium auratum;* in the tuberose and asphodel, where the individual blossoms are smaller, they are gathered together in big upright spikes; in the hyacinth, the clustering is closer still; while in wild garlic, grape-hyacinth, and star-of-Bethlehem, the arrangement assumes the form of a flat-topped bunch or a globular cluster. Of course, small flowers are sometimes

solitary, and large ones sometimes clustered; but as a general rule the tendency is for the big blossoms to trust to their own individual attractions, and for the little ones to feel that union is strength, and to organize accordingly.

Botanists have invented many technical names for various groupings of flowers in particular fashions, with most of which I will not trouble you. It will be sufficient to recall mentally the very different way in which the flowers are arranged in the lily-of-the-valley, the foxglove, the Solomon's-seal, the heath, the cowslip, the sweet-William, the forget-me-not, in order to see what variety natural selection has produced in all these matters. Two instances must serve to illustrate their mode of action. The foxglove turns its one-sided spike toward the sun and the open; its flowers open regularly from below upward, and are fertilized by bees, who enter the blossoms, and whose body is beautifully adapted to come in contact, first with the stamens, and later with the stigma. In the forget-me-not, on the other hand, the unopened flowers are coiled up; but as each one opens, the stem below it lengthens and unrolls, so that at each moment the two or three flowers just ready for fertilization are displayed conspicuously at the top of the apparent cluster.

There are two forms of cluster, however, so specially important that I cannot pass them over here without some words of explanation. These are the umbel and the head, both of frequent occurrence. An umbel is a cluster in which the flowers, standing on separate stalks, reach at last the same level, so as to form a flat-topped

mass, like the surface of a table. An immense family of plants has very small flowers arranged in such an order; they are known as umbellates, and they include carrot and celery. In other families the same form of cluster is seen in ivy and garlic. A head, again, is a cluster in which the individual flowers are set close on very short stalks or none at all in a round ball or a circle. Clover is an excellent example of this sort of coöperation.

If you examine a head of common white Dutch clover, you will see for yourself that it is not, as you might suppose, a single flower, but a thick mass of small white pea-like blossoms, each on a stalk of its own, and each provided with calyx, corolla, stamens, and pistil. They are fertilized by bees; and as soon as the bee has visited each blossom, it turns down and closes over, so as to warn the future visitor that he has nothing to expect there. The flowers open from below and without, upward and inward; and there is always a broad line between the rifled and fertilized flowers, which hang down as if retired from business, and the fresh and upstanding virgin blossoms, which court the bees with their bright corollas. Sometimes you will find a head of clover in which all the flowers save one have already been fertilized; and this one stands up in the center, still waiting for the bees to come and fertilize it.

By far the most interesting form of head, however, is that which occurs in the daisy, the sunflower, the dandelion, and their allies, where the club or coöperative society of united blossoms so closely simulates a single flower as to be mistaken for one by all but botanical

observers. To the world at large a daisy or a dahlia is simply a flower; in reality it is nothing of the sort, but a city or community of distinct flowers, differing widely from one another in structure and function, but all banded together for the purpose of effecting a common object. There is a vast and very varied family of such united flowers, known as the "composites"; it stands at the head of the fivefold group of flowering plants, as the orchids stand at the head of the threefold; and it is so widely spread, it includes so large a proportion of the best-known plants, and it fills so large a space in the vegetable world generally, that I cannot possibly pass it over even in so brief and hasty a history as this of the development of plants on the surface of our planet.

If you pick a daisy, you will think at first sight it is a single flower. But if you look closer into it you will see it is really a great group of flowers — a compound flower head, composed of many dozen distinct blossoms or florets, as we call them. These, however, are not all alike. The florets in the center, which you took no doubt at first sight for the stamens and pistils, are small yellow tubular blossoms, each with a combined corolla of five lobes, little or no visible calyx, five stamens united in a ring round the style, and a pistil consisting of an inferior ovary, with a style divided above into a two-fold stigma. Here we have clear evidence that the plant belongs by origin to the five-petaled group; it rather resembles the harebell, in the plan of its flower, on a much smaller scale; but it has lost almost all trace of a separate calyx, it has its five petals united into a tubu-

lar corolla, it has still its original five stamens, but its carpels are now reduced to one, with a single seed, though traces of an earlier intermediate stage, when the carpels were two, remains even yet in the divided stigma.

So much for the inner flowers or florets in the daisy. The outer ones, which you took at first no doubt for petals, are very different indeed from these central blossoms. They have an extremely curious long, strap-shaped corolla, open down the side, but tubular at its base, as if it had been split through the greater part of its length by a sharp penknife. Instead of being yellow, too, these outer florets are white, slightly tinged with pink, and they form the largest and most attractive part of the whole flower head. Furthermore, they have a style and ovary, but no stamens. Clearly, we have here a flower head with numerous unlike flowers, which at once suggests the idea of a division of labor between the component members. How this division works we shall see in the sequel.

The composites, then, started with florets which had little or no calyx, the sepals having been converted into tiny feathery hairs, used to float the fruit, as in thistle-down and dandelion. They had a corolla of five purple petals, combined into a single tube. Inside this again came five united stamens, and in the midst of all an inferior ovary with a divided stigma. Hundreds of different kinds of composites now existing on the earth retain to this day these essential features, or the greater part of them.

You may take thistle as a good example of the com-

posite flowers in an early stage of development. Here the whole flower head resembles a single large purple blossom. To increase the resemblance, it has below it what seems at first sight to be a big green calyx of very numerous sepals. What is this deceptive object? Well, it is called an "involucre," and it really acts to the compound flower head very much as the calyx acts to the single blossom. The florets having got rid of their separate calyxes, the flower head provides itself with a cup of leaves or bracts, which protect the unopened head in its early stages, and serve to keep off ants or other creeping insects exactly as a calyx does for the single flower. Inside this involucre, again, all the florets of the thistle are equal and similar. Each has a tiny calyx, hardly recognizable as such, made up of feathery hairs which cap the inferior ovary. Within this fallacious calyx, once more, the floret has a purple corolla of five petals, united into a tube. Then come the five united stamens, and the pistil with its divided stigma. This is the simplest form of composite.

To this central type belong a large number of well-known plants. Among them may be mentioned the various thistles, most of which have their involucres, and often their leaves as well, extremely prickly, so as to ward off the attacks of goats and cattle. The burdock, the artichoke, and the globe-thistle also belong to the same central division. Among these earlier composites, however, there is one group, that of the centauries, which leads us gradually on to the next division. Our commonest centaury in Britain (known to boys as "hardheads") has all the florets equal and similar, and

looks in the flower very much like a thistle. But one of its forms, and most of the cultivated garden centauries, have the outer florets much larger and more broadly open than the central ones, so that they form an external petal-like row, which adds greatly to the attractiveness of the entire flower head. Of this type, the common blue cornflower is a familiar example. Clearly the plant has here developed the outer florets more than the inner ones in order to make them act as extra special attractions to the insect fertilizers.

The more familiar type of composites so much cultivated in gardens carries these tactics a step farther. We saw reason to believe in a previous chapter that petals were originally sepals, flattened and brightly colored, and told off for the special attractive function. Just in the same way, the ray-florets of the daisy, the sunflower, the single dahlia, and the aster are florets which have been flattened in order to act as allurements to insects. The ray-floret acts for the compound flower head as the petal acts for the individual blossom.

In many other families of plants besides the composites, we get foreshadowings, so to speak, of this mode of procedure. The outer flowers of a cluster are often rendered larger so as to increase the effective attractiveness of the whole; and sometimes they are sacrificed to the inner one by being deprived of stamens and pistil. But it is the composites that have carried this principle of division of labor farthest, by making the ray-florets into mere petal-like straps, which do no work themselves, but simply serve to attract the fertilizing insects to the compound flower head.

An immense number of these composites with flattened ray-florets grow in our fields or are cultivated in our gardens. In the simpler among them, such as the sunflower and the goldenrod, both ray-florets and central florets are yellow. But in others, such as the daisy, the ox-eye daisy, and the aster, the ray-florets differ in color from those of the center. Of this class one may mention as familiar instances the dahlia, the zinnia, and the pretty coreopsis so common in our gardens. Gardeners, however, are not content to let us admire these flowers as nature made them. They generally "double" them — that is to say, by carefully selecting certain natural varieties, they produce a form in which all the florets have at last become neutral and strap-shaped. This is well seen in the chrysanthemum, where, however, if you open the very center of the double flower head, you will generally find in its midst a few remaining fertile tubular blossoms. Remember, of course, that what we call a "double flower" in a rose, a buttercup, or any other simple blossom is one in which the stamens have been converted into useless petals; while in a composite it is a flower head in which the central florets have been converted into barren ray-florets. In either case, however, the result is the same — the flowers are rendered sterile.

Nature's way is quite different. Here is how she manages the fertilization of one of these ray-bearing composites — say for example the sunflower. The large yellow rays act as advertisements; the bee, attracted by them, settles on the outer edge and fertilizes the flowers from without inward. To meet this habit of his, the

florets of the sunflowers pass through four regular stages. They open from without inward. In the center are unopened buds. Next come open flowers, in which the stamens are shedding their pollen, while the stigmas are still hidden within the tube. Third in order, we get florets in which the stamens have withered, while the stigmas have now ripened and opened. Last of all, we get, next to the rays, a set of overblown florets, engaged in maturing their fertilized fruits. The bee thus comes first to the florets which he fertilizes with pollen from the last plant he visited; he then goes on to florets where he collects more pollen for the next plant to which he chooses to devote his attention.

In this chapter I have dealt chiefly with the coöperative clubbing together of insect-fertilized flowers, for purposes of mutual convenience; but you must not forget that similar clubs exist also among the wind-fertilized blossoms in quite equal profusion. Such are the catkins of forest trees.

Lastly, I ought to add that where the flowers themselves are inconspicuous, attention is often called to them by a bright-colored leaf or group of leaves in their immediate neighborhood. We see an instance of this in the great white spathe or folding leaf which encloses the flowers of the calla lily. In the poinsettia the individual flowers are tiny and unnoticeable; but they are rich in honey, and round them has been developed a great bunch of brilliant leaves which renders them among the most decorative objects in nature. A scarlet salvia similarly supplements its rather handsome flowers by much handsomer calyxes and bracts which make it a

perfect blaze of splendid color. It does n't matter to the plant how it produces its effect; all it cares for is that by hook or by crook it should attract its insects and get itself fertilized.

ABOUT FRUITS

(*Abridged*)

By G. F. Scott Elliot

DURING late autumn there is but little color in the country. Most green grasses have become a dull grayish-green, and the leafless brown and gray branches of the trees are not, at first sight, particularly interesting. But amongst this monotony of sober coloring, points of bright red or flaming scarlet may be noticed here and there. Sometimes it is a spray of hips (the fruit of the rose), or it may be a cluster of hawthorn berries. Most fruits are some shade of red, but every fruit is conspicuous and easily seen.

There is the most extraordinary range in color. The snowberry and dwarf cornel are pure white. The mistletoe is a yellowish green. Pure yellow fruits are not common, except lemons, oranges, and some of the cucumber orders. The bluish-black of the blackberry and of many plums and prunes goes along with a rather peculiar shade of green in the leaves which sets them off. The colors of apples vary; many of them have been rendered a gorgeous, glossy red through cultivation. One of the most beautiful color contrasts in nature is found in the rich black of the olive, with its background of shining white twigs and silver-green leaves. Another very curious harmony is that of the bittersweet, which has an orange-colored case that opens to display the

seeds: these are closed in a bright scarlet fleshy ball. Changes often occur. The lily-of-the-valley fruit is at first green, then becomes flecked with red, and finally is a rich scarlet. Juniper berries change from green to purple.

Now there is always some meaning in nature for any series of facts such as these. Why are these fruits so brightly colored and so conspicuous?

Birds and other animals are intended to scatter the fruits and seeds, and so the fruits must be easily distinguished at a distance. The seeds are taken to some other place, where they germinate and form a new plant. This furnishes the clue and guide to many other peculiarities in fruits and seeds.

The pleasant smell of ripe apples, plums, strawberries, and other fruits also attract birds and other animals. But the sugary juice and delicious flesh is developed entirely for the purpose of making it worth a bird's while to eat it. The amount of sugary matter is enormous, and the seeds seem very small and inconspicuous compared with this luscious mass. The sugar is produced very rapidly toward the end of the ripening period.

The way in which the sugar is formed is not understood, but unripe fruits contain bitter, unwholesome acids and essences which may produce unpleasant effects if the fruits are eaten green. Thus the color is a guide to the animal, who is not supposed to eat the fruit until it is ripe; if eaten green, the seeds inside the fruit are quite destroyed and cannot germinate. Yet animals are so greedy that young birds, young animals of all sorts, will eat green or half-ripe fruit. Throughout all

the millions of years during which fruits have ripened, Nature has every year clearly told young pterodactyls and other lizards, young birds, young monkeys, and young people to wait till the fruit is ripe. None of them have learned to do so.

When investigating the properties of plums, strawberries, and other fruits, you are sure to find here and there one that has decayed and become rotten. In most cases this is because a bird has pecked a hole in it, or because the outside skin has been broken by a wasp. The sugar has then begun to ferment. Why does it do so?

If you gather a few fruits, put them into a jar of sugar-water, and leave it after closing the mouth with a bunch of cotton wool, then in a day or two fermentation begins and alcohol is produced. That is because, on the outside of the fruit, there were hundreds of an objectionable little fungus. It lives upon sugar and turns the latter into alcohol. This yeast fungus is really a living distillery. It lives in the midst of alcohol all its life, dying eventually by alcoholic poisoning, which it has brought about by its own work. This little yeast fungus can be seen only with a microscope. From a rotten fruit it drops on to the ground, where it remains all winter. Next spring certain small insects carry some of this yeast from the earth to next year's fruits. But the skin of the plum or apple, or the hairs on a gooseberry, or the delicate, waxy bloom on a grape, will prevent these insects or wasps from laying open the sugar inside the fruit to the attacks of yeast and other fermenting fungi.

Some fruits appear to have favorites; they seem to prefer that large animals should eat them. If you look

carefully at a piece of orange peel, and cut a small piece across, you will see distinctly small resin pits full of a curious essence which gives the characteristic taste to marmalade. This bitter stuff will prevent wasps from touching the sugar. It is, however, a valuable material, and some kinds of lemons, etc., are grown chiefly for this oil, which is obtained by scraping the peel with a little saucer which is studded with short pins.

Another very curious point about these fleshy fruits (and also ordinary ones) is the strength of the seed inside. It does not look very strong; but an orange seed, for instance, will not be in the least injured if you put it between two glass plates and gradually press upon the upper one to even a pressure of some thirty pounds. Even hemp seed, which seems quite weak, will endure a weight of four pounds. It is impossible to break a prune stone, or to injure a date stone, by standing with your whole weight upon it. Such strength is necessary because many of these seeds are eaten by birds and ground in their crops with bits of china, stones, shells, and the like, which the birds pick up just to help them in crushing their food.

Fruits and seeds would seem to be exposed to some danger when they are lying on the ground. Horses or other heavy animals might tread on them. But the strength of seeds and their shape is such that no harm is likely to accrue. For instance, I arranged a layer of garden earth a quarter of an inch thick on a glass plate; upon the earth I placed four hemp seeds; then I put a fifty-eight pound weight on the top of the seeds. They were not in the least injured, although the seed of the

hemp is not a particularly tough one. Under such conditions the seed simply slips into the earth. This is made easy for it on account of its shape, which is generally rounded above and below. There are also usually wonderfully thickened cells in the shell or coat of a seed, which make it tough and strong.

As regards the animals for whom fruit or seeds are of great importance, birds are of course the commonest. The missel-thrush, or mavis, is especially fond of mistletoe. Now the berry of the mistletoe is exceedingly sticky and glutinous, and in the course of the bird's meal these sticky strings get on to the bill and feathers, so that the mavis wipes its bill on the branch of a tree. When it does so the seed becomes attached to the branch, and is drawn close to the latter when the viscous matter dries up, and so takes root on the branch.

Nightingales and robins eat strawberries and elderberries; blackbirds are very fond of strawberries, gooseberries, and raspberries. Some of the wild African pigeons are exceedingly fond of castor-oil seeds.

We are still ignorant of many details about birds and berries. It is not quite clear why the seeds are not destroyed, though experiments have shown that they are not injured by passing through the body of a bird.

But it is not only birds which eat fleshy fruits and seeds. Even the tiny, industrious ants drag about seeds of certain plants. Sometimes they gather up corn on grasses, such as ant-rice, and store them for use in winter. They even bite off the growing root to prevent the seeds germinating and spoiling. Occasionally they seem to carry the seeds by accident. In other cases there is a

little fleshy excrescence on the seed which they are fond of eating. Cyclamen, snowdrop, violet, and periwinkle seeds are supposed to be carried in this way. Many animals eat fruits. Horses are occasionally fed on peaches in Chile. Rats eat the coffee cherry, and do a great deal of harm in coffee plantations. Pigs, of course, eat all sorts of fruit, and several other mammals do the same, but monkeys live chiefly on fruit. They plunder the banana plantations, and in South Africa melon patches require to be most carefully watched to prevent baboons from destroying them.

Man himself is a great eater of fruit. Not only so, but he has enormously improved and altered wild fruits until they are modified into monsters. The ordinary wild gooseberry weighs about five pennyweight. In 1852 gooseberries which weighed more than thirty-seven pennyweight were in existence. What size the largest gooseberry may be this year is not easy to say. The most usual way of improving fruits is by selecting the finest specimens for reproduction. It is by this means that the original wild banana, which is a rather small fruit with very large seeds and very little flesh, has been altered into something like one hundred and fifty varieties, of which the immense majority have no seed at all. This is a very extraordinary fact, because the seed is the reason for the existence of the fruit. In the case of seedless varieties of the grape, it has been found that it is necessary to carry pollen to the flowers to fertilize them, and the seedless fruit is also very much smaller in this case, not more than a quarter of the size of one that has seeds.

There are several tropical fruits which, with the possible exception of wheat and oats, are more important to mankind than anything else. The breadfruit, which is very common in the South Sea Islands, has a large fruit the size of a melon. When baked in an oven heated by hot stones, it forms a satisfying meal; it is rather like new bread, but has little flavor. Coarse cloth is made of its bark, and the wood is used as timber. The tree also has a milky juice containing India rubber, and is employed for calking canoes. The most interesting point for botanists about this plant is that the fruit is made up of thousands of little flowers, and the fleshy part is really the stalk.

Still more important to mankind is the banana. It is wheat, corn, and potatoes all in one, in tropical and subtropical countries. It is found all over the world wherever there is a hot, moist climate and shelter from wind. It is a most generous plant as regards the amount which it will produce. It will yield about nineteen and a half tons of dry fruit on a single acre, which is about forty times the amount given by potatoes. The yield may be from five hundred to a thousand bunches per acre, and the value of the trade is enormous. A plantation is not beautiful, because the huge leaves break up into irregular, ragged pieces which look untidy. In the tropics it grows everywhere, and with extremely little trouble.

In Egypt and all along the great deserts of Sahara and Asia the graceful stately date palm gives the favorite food of the people. The Arabs grind up the stones to make food for camels, and sometimes ferment the sap to make toddy. The fig, a native of the Persian Gulf, is

cultivated all along the Mediterranean and in India, Australia, and California. It reaches a very great age. There is one at Finisterre said to be several centuries old. Olives are also one of the most important and characteristic Mediterranean trees. The peculiar taste of the dessert olive is obtained by soaking it in lime or potash, and then in vinegar or salt. The pineapple is interesting in every way. The little sharp spines on the edges of the leaves keep animals off, and also make it a little difficult to harvest. The workmen must wear leather trousers to prevent their being cut and torn by the leaves. In Queensland the pineapple is grown in big fields, and about ten thousand fruits can be got from a single acre. It is also grown in the West Indies, in India, and in other tropical countries. If you examine the horny outside skin of the fruit with a sharp penknife, you will find that each little piece of the mosaic is a flower in itself; with a little care the bracts, three sepals, three petals, and six stamens can be distinguished. The whole stem and all its flowers unite to make a compound fruit. Most varieties have no seeds. It is a native of South America.

ABOUT GREAT TREES

By Oliver Wendell Holmes

I WONDER how my great trees are coming on this summer.

Where are your great trees, Sir? said the divinity student.

Oh, all round about New England. I call all trees mine that I have put my wedding-ring on, and I have as many tree-wives as Brigham Young has human ones.

One set's as green as the other, exclaimed a boarder, who has never been identified.

They're all Bloomers, said the young fellow called John.

[I should have rebuked this trifling with language, if our landlady's daughter had not asked me just then what I meant by putting my wedding-ring on a tree.]

Why, measuring it with my thirty-foot tape, my dear, said I. I have worn a tape almost out on the rough barks of our old New England elms and other big trees. Don't you want to hear me talk trees a little now? That is one of my specialties.

[So they all agreed that they should like to hear me talk about trees.]

I want you to understand, in the first place, that I have a most intense, passionate fondness for trees in general, and have had several romantic attachments to certain trees in particular. Now, if you expect me to hold

forth in a "scientific" way about my tree-loves, — to talk, for instance, of the Ulmus Americana, and describe the ciliated edges of its samara, and all that, — you are an anserine individual, and I must refer you to a dull friend who will discourse to you of such matters. What should you think of a lover who should describe the idol of his heart in the language of science, thus: Class, Mammalia; Order, Primates; Genus, Homo; Species, Europeus; Variety, Brown; Individual, Ann Eliza; Dental formula, —

$$i\,\frac{2-2}{2-2}\;c\,\frac{1-1}{1-1}\;p\,\frac{2-2}{2-2}\;m\,\frac{3-3}{3-3},\text{ and so on?}$$

No, my friends, I shall speak of trees as we see them, love them, adore them in the fields, where they are alive, holding their green sunshades over our heads, talking to us with their hundred thousand whispering tongues, looking down on us with that sweet meekness which belongs to huge, but limited organisms, — which one sees in the brown eyes of oxen, but most in the patient posture, the outstretched arms, and the heavy-drooping robes of these vast beings endowed with life, but not with soul, — which outgrow us and outlive us, but stand helpless, — poor things! — while Nature dresses and undresses them, like so many full-sized, but under-witted children.

Did you ever read old Daddy Gilpin? Slowest of men, even of Englishmen; yet delicious in his slowness, as is the light of a sleepy eye in woman. I always supposed "Dr. Syntax" was written to make fun of him. I have

a whole set of his works, and am very proud of it, with its gray paper, and open type, and long ff, and orange-juice landscapes. Père Gilpin had the kind of science I like in the study of Nature, — a little less observation than White of Selborne, but a little more poetry. Just think of applying the Linnæan system to an elm! Who cares how many stamens or pistils that little brown flower, which comes out before the leaf, may have to classify it by? What we want is the meaning, the character, the expression of a tree, as a kind and as an individual. There is a mother-idea in each particular kind of tree, which, if well marked, is probably embodied in the poetry of every language. Take the oak, for instance, and we find it always standing as a type of strength and endurance. I wonder if you ever thought of the single mark of supremacy which distinguishes this tree from those around it? The others shirk the work of resisting gravity; the oak defies it. It chooses the horizontal direction for its limbs so that their whole weight may tell, — and then stretches them out fifty or sixty feet, so that the strain may be mighty enough to be worth resisting. You will find, that, in passing from the extreme downward droop of the branches of the weeping-willow to the extreme upward inclination of those of the poplar, they sweep nearly half a circle. At 90° the oak stops short; to slant upward another degree would mark infirmity of purpose; to bend downwards, weakness of organization. The American elm betrays something of both; yet sometimes, as we shall see, puts on a certain resemblance to its sturdier neighbor.

It won't do to be exclusive in our taste about trees.

There is hardly one of them which has not peculiar beauties in some fitting place for it. I remember a tall poplar of monumental proportions and aspect, a vast pillar of glossy green, placed on the summit of a lofty hill, and a beacon to all the country round. A native of that region saw fit to build his house very near it, and, having a fancy that it might blow down some time or other, and exterminate himself and any incidental relatives who might be "stopping" or "tarrying" with him, — also laboring under the delusion that human life is under all circumstances to be preferred to vegetable existence, — had the great poplar cut down. It is so easy to say, "It is only a poplar," and so much harder to replace its living cone than to build a granite obelisk!

I must tell you about some of my tree-wives. I was at one period of my life much devoted to the young lady population of Rhode Island, a small but delightful State in the neighborhood of Pawtucket. The number of inhabitants being not very large, I had leisure, during my visits to the Providence Plantations, to inspect the face of the country in the intervals of more fascinating studies of physiognomy. I heard some talk of a great elm a short distance from the locality just mentioned. "Let us see the great elm," — I said, and proceeded to find it, — knowing that it was on a certain farm in a place called Johnston, if I remember rightly. I shall never forget my ride and my introduction to the great Johnston elm.

I always tremble for a celebrated tree when I approach it for the first time. Provincialism has no scale of excellence in man or vegetable; it never knows a first-rate

article of either kind when it has it, and is constantly taking second-and third-rate ones for Nature's best. I have often fancied the tree was afraid of me, and that a sort of shiver came over it as over a betrothed maiden when she first stands before the unknown to whom she has been plighted. Before the measuring tape the proudest tree of them all quails and shrinks into itself. All those stories of four or five men stretching their arms around it and not touching each other's fingers, of one's pacing the shadow at noon and making it so many hundred feet, die upon its leafy lips in the presence of the awful ribbon which has strangled so many false pretensions.

As I rode along the pleasant way, watching eagerly for the object of my journey, the rounded tops of the elms rose from time to time at the roadside. Wherever one looked taller and fuller than the rest, I asked myself, — "Is this it?" But as I drew nearer, they grew smaller, — or it proved, perhaps, that two standing in a line had looked like one, and so deceived me. At last, all at once, when I was not thinking of it, — I declare to you it makes my flesh creep when I think of it now, — all at once I saw a great green cloud swelling in the horizon, so vast, so symmetrical, of such Olympian majesty and imperial supremacy among the lesser forest-growths, that my heart stopped short, then jumped at my ribs as a hunter springs at a five-barred gate, and I felt all through me, without need of uttering the words, "this is it!"

You will find this tree described, with many others, in the excellent "Report upon the Trees and Shrubs of

Massachusetts." The author has given my friend the Professor credit for some of his measurements, but measured this tree himself, carefully. It is a grand elm for size of trunk, spread of limbs, and muscular development, — one of the first, perhaps the first, of the first class of New England elms.

The largest actual girth I have ever found at five feet from the ground is in the great elm lying a stone's throw or two north of the main road (if my points of compass are right) in Springfield. But this has much the appearance of having been formed by the union of two trunks growing side by side.

The West Springfield elm and one upon Northampton meadows belong also to the first class of trees.

There is a noble old wreck of an elm at Hatfield, which used to spread its claws out over a circumference of thirty-five feet or more before they covered the foot of its bole up with earth. This is the American elm most like an oak of any I have ever seen.

The Sheffield elm is equally remarkable for size and perfection of form. I have seen nothing that comes near it in Berkshire County, and few to compare with it anywhere. I am not sure that I remember any other first-class elms in New England, but there may be many.

What makes a first-class elm? Why, size, in the first place, and chiefly. Anything over twenty feet of clear girth, five feet above the ground, and with a spread of branches a hundred feet across, may claim that title, according to my scale. All of them, with the questionable exception of the Springfield tree above referred to, stop, so far as my experience goes, at about twenty-two

or twenty-three feet of girth and a hundred and twenty of spread.

Elms of the second class, generally ranging from fourteen to eighteen feet, are comparatively common. The queen of them all is that glorious tree near one of the churches in Springfield. Beautiful and stately she is beyond all praise. The "great tree" on Boston Common comes in the second rank, as does the one at Cohasset, which used to have, and probably has still, a head as round as an apple-tree, and that at Newburyport, with scores of others that might be mentioned. These last two have perhaps been over-celebrated. Both, however, are pleasing vegetables. The poor old Pittsfield elm lives on its past reputation. A wig of false leaves is indispensable to make it presentable.

[I don't doubt there may be some monster-elm or other, vegetating green, but inglorious, in some remote New England village, which only wants a sacred singer to make it celebrated. Send us your measurements, — (certified by the postmaster, to avoid possible imposition), — circumference five feet from soil, length of line from bough-end to bough-end, and we will see what can be done for you.]

WHY OAKS FOLLOW PINES

By Henry D. Thoreau

I HAVE often been asked, as many of you have been, if I could tell how it happened, that when a pine wood was cut down, an oak one commonly sprang up, and *vice versa*. To which I have answered, and now answer, that I can tell, — that it is no mystery to me. As I am not aware that this has been clearly shown by any one, I shall lay the more stress on this point. Let me lead you back into your wood-lots again.

When, hereabouts, a single forest tree or a forest springs up naturally where none of its kind grew before, I do not hesitate to say, though in some quarters still it may sound paradoxical, that it came from a seed. Of the various ways by which trees are known to be propagated, — by transplanting, cuttings, and the like, — this is the only supposable one under these circumstances. No such tree has ever been known to spring from anything else. If any one asserts that it sprang from something else, or from nothing, the burden of proof lies with him.

It remains, then, only to show how the seed is transported from where it grows to where it is planted. This is done chiefly by the agency of the winds, water, and animals. The lighter seeds, as those of pines and maples, are transported chiefly by wind and water; the heavier, as acorns and nuts, by animals.

In all the pines, a very thin membrane, in appearance much like an insect's wing, grows over and around the seed, and independent of it, while the latter is being developed within its base. Indeed, this is often perfectly developed, though the seed is abortive; nature being, you would say, more sure to provide the means of transporting the seed than to provide the seed to be transported. In other words, a beautiful thin sack is woven around the seed, with a handle to it such as the wind can take hold of, and it is then committed to the wind, expressly that it may transport the seed and extend the range of the species; and this it does as effectually as when seeds are sent by mail in a different kind of sack from the patent-office. There is a patent-office at the seat of government of the universe, whose managers are as much interested in the dispersion of seeds as anybody at Washington can be, and their operations are infinitely more extensive and regular.

There is then no necessity for supposing that the pines have sprung from nothing, and I know that I am not peculiar in asserting that they come from seeds, though the mode of their propagation *by nature* has been but little attended to. They are very extensively raised from the seed in Europe, and are beginning to be here.

When you cut down an oak wood, a pine wood will not *at once* spring up there unless there are, or have been, quite recently, seed-bearing pines near enough for the seeds to be blown from them. But, adjacent to a forest of pines, if you prevent other crops from growing there, you will surely have an extension of your pine forest, provided the soil is suitable.

As for the heavy seeds and nuts which are not furnished with wings, the notion is still a very common one that, when the trees which bear these spring up where none of their kind were noticed before, they have come from seeds or other principles spontaneously generated there in an unusual manner, or which have lain dormant in the soil for centuries, or perhaps been called into activity by the heat of a burning. I do not believe these assertions, and I will state some of the ways in which, according to my observation, such forests are planted and raised.

Every one of these seeds, too, will be found to be winged or legged in another fashion. Surely it is not wonderful that cherry trees of all kinds are widely dispersed, since their fruit is well known to be the favorite food of various birds. Many kinds are called bird cherries, and they appropriate many more kinds, which are not so called. Eating cherries is a birdlike employment, and unless we disperse the seeds occasionally, as they do, I shall think that the birds have the best right to them. See how artfully the seed of a cherry is placed in order that a bird may be compelled to transport it — in the very midst of a tempting pericarp, so that the creature that would devour this must commonly take the stone also into its mouth or bill. If you ever ate a cherry and did not make two bites of it, you must have perceived it — right in the center of the luscious morsel, a large earthy residuum left on the tongue. We thus take into our mouths cherry stones as big as peas, a dozen at once, for Nature can persuade us to do almost anything when she would compass her ends. Some wild

men and children instinctively swallow these, as the birds do when in a hurry, it being the shortest way to get rid of them. Thus, though these seeds are not provided with vegetable wings, Nature has impelled the thrush tribe to take them into their bills and fly away with them; and they are winged in another sense, and more effectually than the seeds of pines, for these are carried even against the wind. The consequence is, that cherry trees grow not only here but there. The same is true of a great many other seeds.

But to come to the observation which suggested these remarks. As I have said, I suspect that I can throw some light on the fact, that when hereabouts a dense pine wood is cut down, oaks and other hard woods may at once take its place. I have got only to show that the acorns and nuts, provided they are grown in the neighborhood, are regularly planted in such woods; for I assert that if an oak tree has not grown within ten miles, and man has not carried acorns thither, then an oak wood will not spring up *at once*, when a pine wood is cut down.

Apparently, there were only pines there before. They are cut off, and after a year or two you see oaks and other hard woods springing up there, with scarcely a pine amid them, and the wonder commonly is, how the seed could have laid in the ground so long without decaying. But the truth is, that it has not lain in the ground so long, but is regularly planted each year by various quadrupeds and birds.

In this neighborhood, where oaks and pines are about equally dispersed, if you look through the thickest pine wood, even the seemingly unmixed pitch-pine ones, you

will commonly detect many little oaks, birches, and other hard woods, sprung from seeds carried into the thicket by squirrels and other animals, and also blown thither, but which are overshadowed and choked by the pines. The denser the evergreen wood, the more likely it is to be well planted with these seeds, because the planters incline to resort with their forage to the closest covert. They also carry it into birch and other woods. This planting is carried on annually, and the oldest seedlings annually die; but when the pines are cleared off, the oaks, having got just the start they want, and now secured favorable conditions, immediately spring up to trees.

The shade of a dense pine wood is more unfavorable to the springing up of pines of the same species than of oaks within it, though the former may come up abundantly when the pines are cut, if there chances to be sound seed in the ground.

But when you cut off a lot of hard wood, very often the little pines mixed with it have a similar start, for the squirrels have carried off the nuts to the pines, and not to the more open wood, and they commonly make pretty clean work of it; and moreover, if the wood was old, the sprouts will be feeble or entirely fail; to say nothing about the soil being, in a measure, exhausted for this kind of crop.

If a pine wood is surrounded by a white oak one chiefly, white oaks may be expected to succeed when the pines are cut. If it is surrounded instead by an edging of shrub oaks, then you will probably have a dense shrub-oak thicket.

I have no time to go into details, but will say, in a word, that while the wind is conveying the seeds of pines into hard woods and open lands, the squirrels and other animals are conveying the seeds of oaks and walnuts into the pine woods, and thus a rotation of crops is kept up.

On the 24th of September, in 1857, as I was paddling down the Assabet, in this town, I saw a red squirrel run along the bank under some herbage, with something large in its mouth. It stopped near the foot of a hemlock, within a couple of rods of me, and, hastily pawing a hole with its forefeet, dropped its booty into it, covered it up, and retreated part way up the trunk of the tree. As I approached the shore to examine the deposit, the squirrel, descending part way, betrayed no little anxiety about its treasure, and made two or three motions to recover it before it finally retreated. Digging there, I found two green pignuts joined together, with the thick husks on, buried about an inch and a half under the reddish soil of decayed hemlock leaves — just the right depth to plant it. In short, this squirrel was then engaged in accomplishing two objects, to wit, laying up a store of winter food for itself, and planting a hickory wood for all creation. If the squirrel was killed, or neglected its deposit, a hickory would spring up. The nearest hickory tree was twenty rods distant. These nuts were there still just fourteen days later, but were gone when I looked again, November 21, or six weeks later still.

I have since examined more carefully several dense woods, which are said to be, and are apparently exclu-

sively pine, and always with the same result. For instance, I walked the same day to a small but very dense and handsome white pine grove, about fifteen rods square, in the east part of this town. The trees are large for Concord, being from ten to twenty inches in diameter, and as exclusively pine as any wood that I know. Indeed, I selected this wood because I thought it the least likely to contain anything else. It stands on an open plain or pasture, except that it adjoins another small pine wood, which has a few little oaks in it, on the southeast side. On every other side it was at least thirty rods from the nearest woods. Standing on the edge of this grove and looking through it, for it is quite level and free from underwood, for the most part bare, red-carpeted ground, you would have said that there was not a hard-wood tree in it, young or old. But on looking carefully along over its floor I discovered, though it was not till my eye had got used to the search, that, alternating with thin ferns and small blueberry bushes, there was, not merely here and there, but as often as every five feet and with a degree of regularity, a little oak, from three to twelve inches high, and in one place I found a green acorn dropped by the base of a pine.

I confess, I was surprised to find my theory so perfectly proved in this case. One of the principal agents in this planting, the red squirrels, were all the while curiously inspecting me, while I was inspecting their plantation. Some of the little oaks had been browsed by cows, which resorted to this wood for shade.

After seven or eight years, the hard woods evidently find such a locality unfavorable to their growth, the

pines being allowed to stand. As an evidence of this, I observed a diseased red maple twenty-five feet long, which had been recently prostrated, though it was still covered with green leaves, the only maple in any position in the wood.

But although these oaks almost invariably die if the pines are not cut down, it is probable that they do better for a few years under their shelter than they would anywhere else.

HOW PLANTS MOVE

(Abridged)

By Caroline A. Creevey

ALL living things have the power of motion. A rock is motionless because it is a dead, inert piece of matter. Plants and animals, being alive, possess in common the ability, impelled and guided by some inward power, to move. Not all animals can move from place to place. Many lower orders, like sponges, are fixed to one spot, and can only attract nourishment to themselves. The movements of some plants are so remarkable that it is difficult to believe they are not guided by a sort of intelligence. In many of the lower grades of plants, movement seems free and voluntary. The boat-shaped desmids and diatoms jerk themselves over considerable distances. The cilia (hairlike processes) of some mosses move about in water. Oscillaria are curious one-celled plants which, under the microscope, look and wriggle like angleworms. They are filled with protoplasm, that mysterious something in which lies the life of both animals and plants.

As soon as a living seed touches the ground, or is buried beneath the soil, the plant germ struggles intensely to free itself from its prison within the hard, dry seed coats. Life, hitherto dormant, and motion begin. Nature has endowed her tiny child with many wonderful provisions for the hard battle which it has to fight for

very existence. The sun, air, moisture, and earth are friends and supporters of the little seed. Earthworms, destructive insects, burrowing animals, drought, cold, and hard impenetrable soil are foes against which the baby plant will hardly prevail. The successful seed patiently and persistently pushes its way, overcomes obstacles, appropriates suitable nourishment, grows, blossoms, bears fruit, and fulfills the plan of its life, whether it be a tiny portulaca seed or the winged samara of the haughty maple. Many more seeds perish than conquer in the struggle. The strongest and most favorably situated are those that survive.

Suppose we try to follow a young seed in its efforts to grow. The part which first "feels the thrill of life" is the tip of the radicle, or root. This is a wonderful organ, on which at the start everything depends. Mr. Darwin calls it the brain of the plant. Protected by a cap of hard cells, it pushes toward the center of the earth, possibly acted upon by the attraction of gravitation. Instead, however, of going straight down, it feels around in an irregular, circular movement, as if trying to find the softest, most friable soil. If you are pushing your finger into the ground, see how much easier it is when moving the finger around while pressing downward than when pushing straight and steadily in one direction. Sometimes the circuit traversed by the radicle tip is narrow like an ellipse. Sometimes it is almost like movement back and forth on a straight line. The movement is called nutation, or nodding. Darwin prefixes *circum*, making the word "circumnutation," "nodding all around." All growing parts of the plant — its stem,

leaves, flowers, as well as roots — are in constant nutation, "bowing" to all points of the compass in turn, making longer or shorter ellipses, with greater or less regularity. According to the inherited habit of the plant, this revolving motion is, on the outward curve, from right to left, or from north to west, south, east, and north again, all its parts (when not disturbed by wind) revolving the same way; or the motion is in the opposite direction, from left, on the outward curve, to right. This will be perceived when we remember that all pease and beans, grapevines, and other climbers twine in the same direction. This twining is but an exaggerated circumnutation.

To go back to our root-tip. In its downward course it strikes a stone. Immediately the tip is turned at right angles to its former course. It does not like the stone, and dodges, assuming a horizontal direction. What shall hinder it from keeping on in this newly acquired direction? Does it know when it has passed beyond the stone? Not exactly; but the part of the root just behind the tip knows. It hugs the hard thing which the tip hates, and curves over the edge of the stone, pointing the tip of the root once more in a perpendicular direction. Is there anything more marvelous than this divergent action of the root-tip and the part directly, say half an inch, behind? It is almost as if two brains dwelt in the plant.

Secondary roots, developed from the primary, tend obliquely, not straight, downward, else all the roots would lie bunched together. Tertiary roots, developed from secondary, spread horizontally outward, and thus

the combined roots use all the soil within their reach. All these movements of roots are determined by themselves. External influences, as a moist soil, or a ray of light penetrating the ground, produce still other movements of the sensitive tip, causing it to bend toward the moist soil and away from the light.

Almost simultaneously with the starting of the radicle for the earth, the caulicle or stem which carries the first two leaves (or one leaf in monocotyledons) has an impulse from within prompting it to seek for light. It arches its back in order to push with more force against the opposing mass of earth above. The two legs of the arch gradually elongate, the middle of the arch circumnutating and pushing upward until it breaks through the soil. Then, and not before, the stem straightens, and the cotyledons are brought into an upright position. The illustration of Darwin's, often quoted, is of a man over whom a load of hay has fallen. In order to extricate himself, he will first get upon his hands and knees, and with a wriggling motion from side to side will push with his back upward till he has broken through the hay, when he will draw up his body and stand erect.

A seed never makes a mistake by sending its roots upward through the soil and its caulicle downward. One or the other or both may have to wind quite around the seed before they are rightly started, and such curves are often noticed.

I have said that the habit of circumnutating can be best observed in climbing plants. Such, by means of a curving of the stem, or of tendrils, or of leaf stems, coil

around supports, and tightening, draw the entire plant upward. The morning-glory revolves from east, through north to west, and south to north again; or from right outwardly to left. The young stem makes short coils, the older ones longer. But the tip of the young growing stem is ever stretching out and feeling for something around which to coil. Often such stem-tips are hooked, the better to hold against the wind to their supports. When the plant climbs by means of tendrils or leaf stems, these describe large circles in the air until the support is clasped. It is said that in the tendrils of the passion flower this circular movement can be seen with the naked eye, as easily as the movement of the second-hand of a watch. Some plants have a different and peculiar means of taking hold of upright supports. By means of numerous rootlets springing from the stem, the poison ivy clings to rocks, fences, the bark of trees, etc. The Virginia creeper puts out tendrils which spread their tips against a flat surface in little adhesive suckers or disks.

When we speak of spontaneous leaf movements, we enter verily into the domain of fairyland. How many of us, when children, delighted to touch the leaflets of the sensitive plant and see them shrink from us like frightened things? It is something of a surprise to us now to find other common plants, like partridge pea and the sensitive joint vetch behave in much the same manner. Species of Oxalideæ close quickly after being plucked. Some ferns will not wait to be brought home before they fold their pinnæ together. Successfully to press such plants they must be laid between the pages of a magazine

as soon as they are picked, and then, with stiff covers, they can be firmly bound with a strap and taken home.

Some plant leaves close when the sky is darkened by an approaching shower. These come under the category of sleeping leaves. Most leaves sleep — that is, assume a different position upon the stem at nightfall. Could we see the vegetable world at night, it would present many surprises. All of these sleeping movements seem to have one end in view, namely, the protection of the upper and more sensitive surface of the leaf, in order to prevent excessive radiation of moisture and consequent injury from cold. Plants whose leaves are pinned down in their diurnal position will suffer severely in frosty nights, while those which are allowed to assume their sleeping position will take no injury. In the sleeping position the leaf usually presents its edge to the zenith, instead of its flat surface, twisting and turning its peduncle in order to accomplish this result. A pair of leaflets will shut together, folding the upper surfaces inward. In a species of acacia each leaflet of a pair bends toward its mate, and all drop toward the apex, overlapping one another. The resemblance to leaves is thus quite lost, and the tree looks as if "hung with little dangling bits of string."

In clovers the two lateral leaflets fold toward each other, drooping slightly, and the middle leaf turns backward and falls like a box cover over the edges of the other two. The leaves of sweet clover twist through an angle of ninety degrees, so that the edges of all three are turned toward the zenith, the upper surfaces of the two

outside leaflets facing inward, one twisting to the right, the other to the left.

The pease, beans, lupines, desmodiums, and others of the pulse family present conspicuous examples of sleeping leaves. Most remarkable of all is the *Desmodium gyrans*, a native of India, found in greenhouses and known as the telegraph plant. Each large leaflet is attended by two very small, perhaps interrupted, growths of leaves; for this species probably ranks midway between the one-leafed and three-leaved desmodiums. The large leaflet droops at night, and lies close to the stem. The small lateral leaflets are affected more by changes of temperature, say from 70° to 80° Fahrenheit; they move up and down with little jerks. Sometimes several of these movements occur in a minute, and again they are slow. They seem to jump about for pure mischief and fun, since it cannot be perceived that any good is done to the plant by these movements.

Instances of sleep movements of plants might be indefinitely multiplied, and the botanist — anybody, in fact — may visit by night the shrubs and small plants in his own vicinity with the keen enjoyment which attends the discovery of new truths. As morning dawns the sleeping leaves wake up — that is, resume their day position, reversing the twisting process of the evening before.

The cotyledons, as well as many flower petals, sleep at night, the purpose of which is, of course, to protect the stamens and pistils from frost.

The cause of the sleeping movements of leaves, as well as the nutation of all the plant's parts, is an alternate

growth of opposite sides of the stem, preceded by a swelling of the cells, bending the leaf or leaflet away from the more turgid cells. In addition, highly sensitive leaves have a joint or cushion at their base, called a pulvinus. It consists of a mass of nearly colorless cells, somewhat convex in outline, whose growth has ceased. These cells become turgid more quickly upon one side than the other, causing a movement in the opposite direction. Two thirds of the petiole of *Oxalis sensitiva*, and the whole of the short stems of the leaflets of the sensitive plant, are converted into pulvini. What makes the swelling of the cells? Whatever the answer may be, it is one of those things that "we know not now."

The movements of stamens and pistils have reference to their fertilization. The six stamens of the barberry lie curved under the arched petals. Touch them lightly with a needle point and they spring suddenly toward the pistil, brushing it with their anthers. Some composite flowers possess sensitive stamens. In the chicory the anthers are curved outward. A touch causes them to straighten and bring their pollen along the style of the pistil. In portulaca the stamens spring outward when touched.

Among the spontaneous movements of plants must be included the bursting of pods, already referred to, by which seeds are scattered in every direction.

The movements of insectivorous leaves have also been described. The movement of the sundew leaf when it closes over the hapless fly caught upon its gland-tipped bristles can be plainly seen. In cases like these the insects have a tardy revenge, in that the digestive

powers of the leaf are soon exhausted. In the sundew, at least, after a few repetitions of the process, the bristles become rigid, the leaf turns yellow and dies; a warning example, perhaps, of the effect of high living.

PLANTS THAT EAT ANIMALS

By L. H. Bailey, Jr.

IT is an interesting discovery of modern science that many plants catch small animals and eat them. It is a discovery which taxes our credulity if we accept it, and still one which is easy of verification by every one. Few discoveries relating to animals and plants have excited more wonder or called forth more comment than this. This comment has not been confined to scientific journals; nearly every periodical has had something to say about it.

> "What's this I hear
> About the new carnivora?
>   Can little plants
>   Eat bugs and ants
>   And gnats and flies? —
> A sort of retrograding:
>   Surely the fare
>   Of flowers is air,
>   Or sunshine sweet;
>   They should n't eat,
> Or do aught so degrading."

Although the statement that many plants are truly carnivorous is startling, it is nevertheless verified by abundant investigations, and it has taken its place among the undisputed facts of botanical science. We can best understand the nature of carnivorous plants by studying two or three common species.

The curious sidesaddle flower or pitcher plant occurs in mossy swamps all through the Northeastern States,

while southward there are other and more peculiar species. The leaves of these odd plants are transformed into long, tight trumpets or pitchers, which always contain water. Berry pickers who frequent swamps for whortleberries and cranberries often know them as "Indian dippers," and they use them as cups to dip water from the creek. A single large and very curious purple flower nods from a long stem in spring and from its fancied resemblance to a sidesaddle has originated one of the popular names of the plant. If the contents of a pitcher be examined the fluid will be found to contain quantities of dead and decaying insects which have fallen into it. A study of the pitcher will soon convince us that the presence of the insects is not purely accidental. They are attracted to the open pitcher, light upon its rim, and, venturing too far, they fall into or slide down the cavity, and they are prevented from making an escape by the stiff and sharp hairs which point downwards like so many bayonets. When they have fallen into the liquid, which is not entirely water, they are soon drowned, and the plant feeds upon their remains.

Our Northern pitcher plant is less actively insectivorous than some of the Southern species, and especially less than the *Sarracenia variolaris*, which has been minutely studied. In this species a hood or cover projects over the mouth of the pitcher, excluding all rain. The pitcher secretes a viscid liquid, which speedily dispatches all unfortunate insects that fall into it. About the mouth of the pitcher is a secretion of a sugar-like substance, which attracts numerous flies and smaller insects. This secretion extends even down the outside of the pitcher

to the ground, presenting a honey-baited pathway, which arrests all wandering insects, especially ants, and allures them upward to the fatal opening. Once upon the rim of the pitcher they gorge themselves with the delectable honey, unwarily getting a little farther down on the inside, until finally they slip on the glossy surface and soon find themselves inextricably entangled among the bristling, deflexed hairs. All attempts to escape are futile, and they soon come in contact with the viscid liquid, from which they are never rescued. So perfect is this fly-trap that a fly or other insect never escapes from it. It is said that plants are sometimes grown about the house as fly-traps, but although they catch flies in abundance, the odor from the decaying insects is not pleasant. The plant absorbs food from the mingled contents of its pitchers. So persistently do some of the Sarracenias catch flies that they cannot be cultivated on account of the bursting of the pitchers from overloading unless the mouths are closed with cotton. Some animals have learned of the peculiar habits of the Sarracenias and have taken to stealing the food which the plant has caught. Two species of insects, a fly and a moth, are habitually associated with some of the Southern pitcher plants. They have learned apparently to evade the seductive honey and the fatal trap, and in some manner drop their eggs into the mingled contents of the pitcher, where the larvæ thrive. Birds are said to slit the pitchers to secure the insects.

A very singular plant, closely allied to the Sarracenias, is the Darlingtonia of California. This plant grows in the vicinity of Mount Shasta at an altitude of one thousand

to six thousand feet. The pitchers are eighteen to twenty-four inches high and an inch or less in diameter, except at the inflated top. They are spirally twisted about half a revolution, the twist being usually to the left. Running lengthwise the pitcher is a narrow wing, extending from the ground to the orifice. The top of the pitcher is an inflated sac two to four inches across, with translucent dots or windows in its roof, and having an opening underneath an inch or less in diameter. At the upper extremity of this opening hangs a two-lobed blade, resembling a fish's tail, which is attractively colored and peculiarly twisted, and furnished on its inside with stiff hairs pointing upwards. Like the Sarracenias this plant has the honey-bait about the mouth of the pitcher and the secreted fluid in the tube. A crawling insect finds the base of the pitcher, and wishing to explore follows the fence-like wing upwards until he comes to the sweet-lipped brim. Other insects are at once attracted by the gaudy fish-tail blade, and they light upon its outer surface. This blade is twisted in such a manner, that an insect lights upon the outside, follows the enticing folds, and presently finds himself upon the inside of it. He walks upward easily, but the instant he turns back the menacing bayonet hairs prevent his progress. He keeps on and now he begins to scent the feast of honey which is spread for him. He enters the opening, eats, becomes satisfied, and decides to leave. He looks for a place of egress, and is attracted by the pretty windows in the roof. He becomes bewildered in this dim Castle of Doubt, and every step over the deceptive hairs brings him nearer his doom.

The sundew is an unattractive plant, which grows in swamps and wet places. The peculiar ladle-like leaves are trimmed with bristling hairs, which bear on their ends little drops of glistening "dew" which give the plant its name. These hairs are known as tentacles. If any object falls upon the leaf, the tentacles begin slowly to move forwards, until they finally shut down tightly over the object, as we can imagine the fingers to shut down over an object in the palm of the hand. We will suppose this object to be an insect. As soon as it alights upon the leaf, the tentacles throw out more of the viscid "dew," which holds him more securely, and the more he struggles the more the substance is poured out and the faster the surrounding tentacles come to the aid of the weak ones near the center of the leaf. Once upon the leaf the insect is doomed. The leaves of the drosera or sundew lie upon the ground, and they are therefore more apt to be visited by ants and other crawling insects. If an unfortunate ant comes in contact with one of the extended tentacles he is caught by the attractive glue, and the tentacle at once begins to move inwards just as a finger is bent over to the palm. The tentacle does not go alone, but its neighbors come to the feast as well. When the insect is thoroughly entrapped under a number of deflexed tentacles, an acid secretion is thrown out which digests it. After the feast is over, the tentacles return to their former position and lie in wait for another victim. If a little stone should drop on the leaf the tentacles are summoned in more slowly than before, and finding out their mistake they return to their normal position much more rapidly. A

tentacle will often begin to move in ten seconds after it is touched, and in from one hour to four hours it will be completely deflexed. Mr. Darwin fed beef to plants of sundew and they accepted it as readily as an insect. Although the pressure of a gnat's foot will cause a tentacle to move, a drop of rain will not affect it.

The Venus's fly-trap, or dionæa, of North Carolina, is a botanical ally of the interesting sundew, but its contrivance for capturing insects is very different. The leaves are borne at the base of the flower-stalk, as in the sundew. The trap portion has two valves or jaws, about the edge of which are stiff and insensitive hairs or bristles. The trap secretes no viscid material to hold the insect. Two or three hairs on the inner faces of these jaws are highly sensitive, and the slightest touch will cause the trap to fly together, the bristles interlocking like the teeth of a bear-trap. The unwary insect is caught before he thinks of danger. The jaws do not at once close completely, however. The teeth interlock and the jaws remain a little ajar, and this allows any very small insect, which is not worth the plant's consideration, to escape. A larger insect, upon finding escape impossible, would again touch the sensitive hairs in his struggles, and the jaws would close tightly and crush him. As soon as the jaws come together a digestive secretion is poured out from the leaf, and the jaws remain in contact until the insect is digested — eaten up! They then open to allure another insect. The little hairs, although sensitive to the slightest touch, are not influenced by wind or rain.

ARE MUSHROOMS PLANTS?

(Abridged)

By Arabella B. Buckley

THE following day saw the classroom full, and from the benches eager eyes were turned to the eight windows, in each of which stood one of the older boys at his microscope ready for work. For under those microscopes the Principal always arranged some object referred to in his lecture and figured in diagrams on the walls, and it was the duty of each boy, after the lecture was over, to show and explain to the class all the points of the specimen under his care. These boys were always specially envied, for though the others could, it is true, follow all the descriptions from the diagrams, yet these had the plant or animal always under their eye. Discussion was at this moment running high, for there was a great uncertainty of opinion as to whether a mushroom could be really called a plant when it had no leaves or flowers. All at once the hush came, as the Principal stepped into his desk and began: —

"Life is hard work, boys, and there is no being in this world which has not to work for its living. You all know that a plant grows by taking in gases and water, and working them up into sap and living tissue by the help of the sunshine and the green matter in their leaves; and you know, too, that the world is so full of green plants that hundreds and thousands of young seedlings can

never get a living, but are stifled in their babyhood or destroyed before they can grow up.

"Now there are many dark, dank places in the world where plants cannot get enough sunlight and air to make green coloring matter and manufacture their own food. And so it comes to pass that a certain class of plants have found another way of living, by taking their food ready-made from other decaying plants and animals, and so avoiding the necessity of manufacturing it for themselves. These plants can live hidden away in dark cellars and damp cupboards, in drains and pipes where no light ever enters, under a thick covering of dead leaves in the forest, under fallen trunks and mossy stones; in fact, wherever decaying matter, whether of plant or animal, can be found for them to feed upon.

"It is to this class, called 'fungi' which includes all mushrooms and moulds, mildews, smuts, and ferments, that the mushroom belongs which we found yesterday making the fairy rings. And, in truth, we were not so far wrong when we called them pixies or imps, for many of them are indeed imps of mischief, which play sorry pranks in our stores at home and in the fields and forests abroad. They grow on our damp bread, or cheese, or pickles; they destroy fruit and corn, hop and vine, and even take the life of insects and other animals. Yet, on the other hand, they are useful in clearing out unhealthy nooks and corners, and purifying the air; and they can be made to do good work for those who know how to use them; for without ferments we could have no vinegar, nor even the yeast which lightens our bread.

"I am going to-day to introduce you to this large

vagabond class of plants, that we may see how they live, grow, and spread, what good and hard work they do, and how they do it. And before we come to the mushrooms, which you know so well, we must look at the smaller forms, which do all their work above ground, so that we can observe them. For the fungi are to be found almost everywhere. The film growing over manure heaps, the yeast plant, and the vinegar plant; the moulds and mildews covering our cellar walls and cupboards, or growing on decayed leaves and wood, on stale fruit, bread, or jam, or making black spots on the leaves of the rose, the hop, or the vine; the potato fungus, eating into the potato in the dark ground and producing disease; the smut filling the grains of wheat and oats with disease, the ergot feeding on the rye, the rust which destroys beetroot, the rank toadstools and puffballs, the mushroom we eat, and the truffles which form even their fruit underground, — all these are fungi, or lowly plants which have given up making their own food in the sunlight, and take it ready-made from the decaying mould, the root, the leaf, the fruit, or the germ on which they grow. Lastly, the diseases which kill the silkworm and the common house fly, and even some of the worst skin diseases in man, are caused by minute plants of this class feeding upon their hosts.

"In fact, the fungi are so widely spread over all things living and dead, that there is scarcely anything free from them in one shape or another. The minute spores, now of one kind, now of another, float in the air, and settling down wherever they find suitable food, have nothing more to do than to feed, fatten, and increase,

which they do with wonderful rapidity. Let us take as an example one of the moulds which covers damp leaves, and even the paste and jam in our cupboard. I have some here growing upon a basin of paste, and you see it forms a kind of dense white fur all over the surface, with here and there a bluish-green tinge upon it. This white fur is the common mould, but I must warn you that these minute moulds look very much alike until you examine them under the microscope, and though they are called white, blue, or green moulds, yet any one of them may be colored at different times of its growth.

"All these plants began with a spore or minute colorless cell of living matter, which spends its energy in sending out tubes in all directions into the leaves, fruit, or paste on which it feeds. The living matter, flowing now this way, now that, lays down the walls of its tubes as it flows, and by and by, here and there a tube, instead of working into the paste, grows upwards into the air and swells at the tip into a colorless ball in which a number of minute seed-like bodies called spores are formed. The ball bursts, the spores fall out, and each one begins to form fresh tubes, and so little by little the mould grows denser and thicker by new plants starting in all directions.

"Few people who hastily scrape a mould away, vexed to find it on food or damp clothing, have any idea what a delicate and beautiful structure lies under their hand. These moulds live on decaying matter, but many of the mildews, rusts, and other kinds of fungus, prey upon living plants such as the 'smut' of oats, and the 'bunt' which eats away the inside of the grains of wheat, while

another fungus attacks its leaves. There is scarcely a tree or herb which has not one fungus to prey upon it, and many have several, as for example, the common lime tree, which is infested by seventy-four different fungi, and the oak by no less than two hundred.

"So these colorless food-taking plants prey upon their neighbors, while they take their oxygen for breathing from air. The 'ferments,' however, which live inside plants or fluids, take even their oxygen for breathing from their hosts.

"If you go into the garden in summer and pluck an overripe gooseberry, you will probably find that the pulp looks unhealthy and rotten near the split, and the gooseberry will taste tart and disagreeable. This is because a small fungus has grown inside, and worked a change in the juice of the fruit. At first this fungus spread its tubes outside and merely fed upon the fruit, using oxygen from the air in breathing; but by and by the skin gave way, and the fungus crept inside the gooseberry where it could no longer get any fresh air. In this dilemma it was forced to break up the sugar in the fruit and take the oxygen out of it, leaving behind only alcohol and carbonic acid which give the fermented taste to the fruit.

"So the fungus feeds and grows in nature, and when man gets hold of it, he forces it to do the same work for a useful purpose, for the grape-fungus grows in the vats in which grapes are crushed and kept away from air, and tearing up the sugar, leaves alcohol behind in the grape-juice, which in this way becomes wine. So, too, the yeast fungus grows in the malt and hop liquor, turning

it into beer; its spores floating in the fluid and increasing at a marvelous rate, as any housewife knows who, getting yeast for her bread, tries to keep it in a corked bottle.

"The yeast plant has never been found wild. It is only known as a cultivated plant, growing on prepared liquor. The brewer has to sow it by taking some yeast from other beer, or by leaving the liquor exposed to air in which yeast spores are floating; or it will sow itself in the same way in a mixture of water, hops, sugar, and salt, to which a handful of flour is added. It increases at a marvelous rate, one cell budding out of another, while from time to time the living matter in a cell will break up into four parts instead of two, and so four new cells will start and bud. A drop of yeast will very soon cover a glass slide with this tiny plant.

"But perhaps the most curious of all the minute fungi are those which grow inside insects and destroy them. You may often see a dead fly sticking to the window pane with a cloudy white ring round it; this poor fly has been killed by a little fungus called *empusa museæ*. A spore from a former plant has fallen perhaps on the window pane, or some other spot over which the fly has crawled, and being sticky has fixed itself under the fly's body. Once settled on a favorable spot it sends out a tube, and piercing the skin of the fly, begins to grow rapidly inside. There it forms little round cells one after the other, something like the yeast cells, till it fills the whole body, feeding on its juices; then each cell sends a tube out again through the fly's skin, and this tube bursts at the end, and so new spores are set free. It is

these tubes, and the spores thrown from them, which you see forming a kind of halo round the dead fly as it clings to the pane. Other fungi in the same way kill the silkworm and the caterpillars of the cabbage butterfly. Nor is it only the lower animals which suffer. When we once realize that fungus spores are floating everywhere in the air, we can understand how the terrible microscopic fungi called bacteria will settle on an open wound and cause it to fester if it is not properly dressed.

"Thus we see that these minute fungi are everywhere. The larger ones, on the contrary, are confined to the fields and forests, damp walls, and hollow trees; or wherever rotting wood, leaves, or manure provide them with sufficient nourishment. Few people have any clear ideas about the growth of a mushroom, except that the part we pick springs up in a single night. The real fact is, that a whole mushroom plant is nothing more than a gigantic mould or mildew, only that it is formed of many different shaped cells, and spreads its tubes underground or through the trunks of trees instead of in paste or jam, as in the case of the mould.

"The part which we gather and call a toadstool or a puffball is only the fruit, answering to the round balls of the mould. The rest of the plant is a thick network of tubes. These tubes spread underground and suck in decayed matter from the earth. They form the *mycelium* or 'mushroom spawn,' which the dealers use to spread over the ground for new crops. Out of these underground tubes there springs up from time to time a swollen round body no bigger at first than a mustard seed. As it increases in size, it comes above ground and

grows into the mushroom or spore case, answering to the round balls which contain the spores of the mould. At first this swollen body is egg-shaped, the top half being largest and broadest, and the fruit is then called a 'button mushroom.' Inside this ball are now formed a series of folds made of long cells, some of which are soon to bear spores just as the tubes in the mould did, and while these are forming and ripening, a way out is preparing for them. For as the mushroom grows, the skin of the lower part of the ball is stretched more and more, till it can bear the strain no longer and breaks away from the stalk; then the ball expands into an umbrella, leaving a piece of torn skin, called the veil, clinging to the stalk.

"All this happens in a single night, and the mushroom is complete, with a stem up the center and a broad cap, under which are the folds which bear the spores. Thus much you can see for yourselves by finding a place where mushrooms grow and looking for them late at night and early in the morning so as to get the different stages. But now we must turn to the microscope, and cutting off one of the folds, which branch out under the cap like the spokes of a wheel, take a slice across it, and examine.

"First, under a moderate power, you will see the cells forming the center of the fold and the layer of long cells which are closely packed all round the edge. Some of these cells project beyond the others, and it is they which bear the spores. We see this plainly under a very strong power when you can distinguish the sterile cells and the fertile cells projecting beyond them, and each bearing four spore-cells on four little horns at its tip.

"These spores fall off very easily, and you can make a pretty experiment by cutting off a large mushroom head in the early morning and putting it flat upon a piece of paper. In a few hours, if you lift it very carefully, you will find a number of dark lines on the paper, radiating from a center like the spokes of a wheel, each line being composed of the spores which have fallen from a fold as it grew ripe. They are so minute that many thousands would be required to make up the size of the head of an ordinary pin, yet if you gather the spores of the several kinds of mushrooms, and examine them under a strong microscope, you will find that even these specks of matter assume different shapes in the various species.

"You will be astonished too at the immense number of spores contained in a single mushroom head, for they are reckoned by millions; and when we remember that each one of these is the starting point of a new plant, it reminds us forcibly of the wholesale destruction of spores and seeds which must go on in nature, otherwise the mushrooms and their companions would soon cover every inch of the whole world.

"As it is, they are spread abroad by the wind, and wherever they escape destruction, they lie waiting in every nook and corner till, after the hot summer, showers of rain hasten the decay of plants and leaves, and then the mushrooms, toadstools, and puffballs grow at an astounding pace. There they work, thrusting their tubes into twigs and dead branches, rotting trunks and decaying leaves, breaking up the hard wood and tough fibers, and building them up into delicate cells,

which by and by die and leave their remains as food for the early growing plants in the spring. So we see that in their way the mushrooms and toadstools are good after all, for the tender shoot of a young seedling plant could take no food out of a hard tree trunk, but it finds the work done for it by the fungus, the rich nourishment being spread around its young roots ready to be imbibed.

"To find our fairy-ring mushrooms, however, we must leave the wood and go out into the open country, especially on the downs and moors and rough meadows, where the land is poor and the grass coarse and spare. There grow the nourishing kinds, most of which we can eat, and among these is the delicate little mushroom which makes the fairy ring. When a spore of this mushroom begins to grow, it sucks up vegetable food out of the earth and spreads its tubes underground, in all directions from the center, so that the mycelium forms a round patch like a thick underground circular cobweb. In the summer and autumn, when the weather is suitable, it sends up its delicate pale-brown caps which we may gather and eat without stopping the growth of the plant.

"This goes on year after year underground, new tubes always traveling outwards till the circle widens and widens like the rings of water on a pond, only that it spreads very slowly, making a new ring each year, which is often composed of a mass of tubes as much as a foot thick in the ground, and the tender tubes in the center die away as the new ones form a larger hoop outside.

"But all this is underground; where then are our fairy rings? Here is the secret. The tubes, as we have

seen, take up food from the earth and build it into delicate cells, which decay very soon, and as they die make a rich manure at the roots of the grass. So each season the cells of last year's ring make a rich feeding ground for the young grass, which springs up fresh and green in a fairy ring, while outside this emerald circle the mushroom tubes are still growing and increasing underneath the grass, so that next year, when the present ring is no longer richly fed, and has become faded and brown like the rest of the moor, another ring will spring up outside it, feeding on the prepared food below.

"In bad seasons, though the tubes go on spreading and growing below, the mushroom fruit does not always appear above ground. The plant will only fruit freely when the ground has been well warmed by the summer sun, followed by damp weather to moisten it. This gives us a rich crop of mushrooms all over the country, and it is then you can best see the ring of fairy mushrooms circling outside the green hoop of fresh grass. In any case the early morning is the time to find them; it is only in very sheltered spots that they sometimes last through the day, or come up toward evening.

"Learn to know the mushrooms, their different shapes and colors, and the special nook each one chooses for its home. Look around in the fields and woods and take note of the decaying plants and trees, leaves, and bark, insects and dead remains of all kinds. Upon each of these you will find some fungus growing, breaking up their tissues and devouring the nourishing food they provide. Watch these spots, and note the soft spongy soil which will collect there, and then when the spring

comes, notice what tender plants flourish upon these rich feeding grounds. You will thus see for yourselves that the fungi, though they feed upon others, are not entirely mischief-workers, but also perform their part in the general work of life."

ABOUT OLD WALLS

(Abridged)

By G. F. Scott Elliot

ANY old wall, provided it is well out in the country, is pretty sure to be interesting. At first it seems to have only a dull gray or neutral tint, but if one goes to four or five feet distance, one discovers that many shades of brown, red, white, and black go to make this gray. But the extraordinary beauty of such a wall is only visible when one peers and scrutinizes the surface very slowly and carefully with the eyes six or seven inches away from it. The change is then most remarkable. The entire surface is spotted or dusted, sprinkled or entirely covered by thick lichen stains and crusts. The original color of the stone is nowhere visible. The lichens show the most delicate shades and contrasts in color; all pleasing and all blending together in harmonious general tones. The fruit of these lichens is like a minute saucer or platter, generally with a thin rim or border, but it is exceedingly small, probably only one sixteenth of an inch in diameter, or even less. The smallest of these crust lichens form continuous, very thin, coatings, covering the stone; and against this background the little saucer-like fruits show up quite distinctly.

The coating itself varies from "bright yellow, pale

ocher, citron, chestnut color, to mouse color, different shades of gray and green, cream color, lead color, blue-black, or pure black, tawny, brown, rusty red, or pure white." The cups of one kind are black, whilst those of another are generally reddish brown. But they may be a ghostly pale hue which stands out plainly against the gray-green background of the frond. Sometimes they are of the richest crimson or lake, set against a pure snow-white crust. Those of *Lecanora vitellina* are, though tiny, a brilliant yellow, and quite startling when first one notices them. Many of these contrasts and shades are never used by artists, and even from the mere artistic point of view they have great interest.

But if, after spending a few minutes in carefully looking over the rocks at a distance of six or seven inches, one stands up and goes back four or five feet, the whole of this color scheme fades away and there is only the monotonous gray or neutral tint of the wall.

Now why is this? Why should these delicate and exquisite shades be wasted on such minute and scarcely distinguishable forms?

There are always two sides from which one can look at any subject, namely, the inside and the outside. From the inside (that is, from the point of view of the little lichen itself) these colors are decidedly useful. Small insects crawl about on such walls or hover a few inches in front of them, and to those insects these cups will be as conspicuous and attractive as a scarlet geranium is to ourselves.

Just as we go to look at a geranium, so those insects fly toward the cups and crawl about on them. Then

when the spores and dust of the lichen begin to stick in their hairs and feet, they go to a bare place and clean them off. Thus the spores and dust are carried to a new part of the rock, where they will grow if they can find an unoccupied place. The taste in color of these insects, moreover, is apparently not very different from that of man.

But perhaps a still more interesting point of view is that from the outside. Why are those lichens there? What are they doing, and are they of any use?

The general scheme of Nature is to cover the whole world with green, so that every ray of sunlight may find a working leaf or green frond ready to welcome it and use it. Nature abhors bare rock, barren sand, and empty water, and never ceases to try to bring it under that beautiful covering of green plants and active vegetable life which supports both man and animals.

We all know that there is a romance in the story of man's colonies. First the explorer searches out the country; then the pioneer frontiersman settles and builds his log hut or rough shanty. Next comes the frontier village, which may perhaps become a crowded city where active, valuable work is carried on.

The story of the colonizing of rocks and stones by plants is just as interesting. These tiny lichens are almost the first pioneers, and prepare the ground for those that follow. Upon that bare rock, life is terribly severe. The frost shatters it, sunshine heats it until it almost burns the hand in summer. Floods of rain or of sleet beat against it, and it may be frozen over for weeks. What plant can stand such conditions? Only these

minute, tiny, scarce visible films! Gradually new lichen crusts develop upon it. They cover over the first pioneers; first they suffocate them and afterward devour their remains. Nature is very businesslike and severe in her working. The lichen crust may be now about one sixteenth of an inch thick. It is a very slow process. There is a story of a boy who noticed a patch of lichen near his father's door. He went away to Kamchatka or somewhere and came back a very old man of eighty-five years; but he found that the lichen patch was just the same size as when he went away. That, however, is just a story! At any rate, one of these little crust-lichens has been known to increase a sixtieth of an inch between the end of February and that of September.

Now if one tries to realize what the life of such a lichen crust must be, it is obvious that the stone below it must be a little corroded or weathered, and remains of the first choked pioneers, bacteria, and possibly tiny insects or animalcula will be under the crust, which may now be one sixteenth of an inch thick. It is the turn now of other lichens to colonize it. These may be the little trumpet or horn and cup lichens, or perhaps the larger gray kinds which have leaf-like fronds and form circles of perhaps eight to ten inches in diameter. The crust-lichen is overgrown, broken up, disorganized, and devoured by these newcomers, who are helped by bacteria, insects, and animalcula which shelter below them. They may increase two thirds of an inch in one year.

But very soon after this, one notices a few inconspicuous green mosses; at first in crevices between the stones or in hollows, and not remarkable, they soon increase

and form trailing sprays or branches which grow very quickly. Branches of moss four or five inches long extend over the leafy lichens in a season. The horn and cup lichens struggle on, but they cannot keep pace with the rapid life of the moss, and soon our wall is covered by beautiful moss turfs. Underneath such a turf there may be an inch or so of good soil (dead moss and dust with lichen and insect bodies). Worms, insects, etc., shelter and flourish and multiply in this soil.

But the turn of the moss is coming. Here a few grass blades, there a tiny plant of sandwort, possibly a rock bedstraw, begin to root themselves in the moss.

If people would only let the wall alone, it would soon be festooned with hanging plants, and producing quantities of grass, but somebody is sure to find that it looks very untidy, and everything is torn off the wall, which again looks new and raw and clean. Then of course the pioneer lichens begin again!

Some very interesting and remarkable facts have been discovered about the way in which lavas and basalts have been occupied by the plant world. In the great volcanic eruption of 1883, the whole island of Krakatoa was covered by hot lava and glowing ashes. In 1884 and 1885 the sunsets were remarkable for a curious fiery red or orange glow, which was supposed to be due to the volcanic dust of that explosion. It is said that the dust traveled three times round the earth. However that may be, on Krakatoa island there was left a "clean slate." There were neither bacteria, nor leaf mould, nor living plants of any kind; no spores or seeds could have endured the fiery furnace of the eruption. Three years

afterwards the botanist Treub visited the island. He found that the rocks had been first covered by thin layers of minute fresh-water algæ, but that ferns were then occupying and inhabiting the lavas. Eleven kinds of ferns, and but very few other plants, were discovered.

People were interested in this, and Dr. A. F. W. Schimper then visited another volcano which had been pouring out huge streams of lava in 1843. He found that there were still plenty of ferns, but also numbers of shrubs and other plants. Yet even then there were no trees, and there was no continuous mantle of green plants such as we are accustomed to in this country. He also found many plants growing on the lava which are generally found on the branches of trees, that is, which can do without a thick layer of soil. He also found quantities of a pitcher plant, which lives mainly on insects caught in its pitchers.

This does not at first sight seem to agree at all with what has been given for the walls. It is true that sometimes in the Highlands one comes across quantities of the bladder fern and others growing on the "screes," or streams of broken, angular stones, filling small gullies, and spreading out at the base over a considerable space. Often these ferns seem to be all that can thrive in amongst the stones. But in a mild and temperate country like England, one would expect things to proceed differently. And in fact they do so. Every one must have noticed a green stain which covers wet walls, stones, stucco, even marble statues, and especially tree bark in wet or damp situations. This is a minute green seaweed, a pretty object for the microscope. This, of

course, is the first stage of colonization. It is followed by mosses of all sorts.

But there is a still more interesting series in a climate resembling that of England. The lava-flows from Mount Vesuvius have been investigated by several observers. There it was found that the first inhabitants were lichens and small green seaweeds; then "different mosses occupied the lava over which a certain quantity of vegetable dust had been scattered." After this, scattered ferns and even small shrubs could be seen on flows which were red-hot only twenty years before, whilst on old lava fields herbs, shrubs, bushes, trees, and even true woods had developed.

Yet in Greenland lava-flows dating from 1724–29 are still only covered by crust-lichens and a very few of the stone-mosses! In Sumatra, on the other hand, the volcano of Tamboro, which in 1815 had entirely destroyed its vegetation, was covered with a fine young wood in 1874! The strong heat and abundant moisture of Sumatra favors, whilst the climate of Greenland prevents, the rapid growth of good soil.

Near Glasgow one sees great heaps of shale, which are often mistaken for natural hills. This is or was virgin soil, never occupied by plants, and entirely destitute of leaf mould or any sort of organic plant food. If one scrambles to the top of one of these heaps, it is easy to see all the details of the occupation. Long underground runners of coltsfoot and of horsetail are climbing up the sides, fringes of creeping buttercup, couchgrass, and other hardy weeds occupy, every year, a little more of the flanks, but, on the top, one very soon finds that the

dust of the atmosphere, aided by weathering, has afforded a chance to mosses, to hawkweeds, and other rock plants. These in time cover the top, and soon hardy grasses and weeds form a regular turf on the top of the shale.

All over the sides of the heap there will be hundreds of a rare groundsel, which is not really a native, and never occurs except on such places. In a grass field close by, hundreds of thousands of ragwort make a glorious golden carpet; in the marshy part of the meadow the water ragwort may be found. In the cottage gardens and here and there along the roadside the common groundsel is flourishing abundantly. These plants never interfere with or encroach upon one another's grounds. Every year thousands of ragweed and groundsel seeds must be blown on to the shale heap, but they never manage to grow there. It is only the foreigner, the viscid groundsel, accustomed to a very hot and dry climate, and with sticky leaves which catch atmospheric dust and probably insects, that can exist on the bare shaly sides. These slopes of shale are easily heated by the sun, and at the same time radiate the heat rapidly away, so that the viscid groundsel must have a very hard time of it. When its roots have worked up the shale a little, and its dead leaves have covered the surface with mould and organic matter, then possibly others, true British plants, can get a footing and suppress it.

Along railway tracks, also, the ballast forms a very hot, a very dry, and a very barren soil. Many of the regular railway track plants are foreigners from the far south, even from the sunny shores of the Mediterranean.

They are mostly annuals, such as the little toadflax, which can just manage to exist under those conditions. Of course the sides of the banks and of cuttings on railways are generally formed of good earth or soil, and support a rich and flourishing flora of true Britons.

Besides these slow, laborious lichens, mosses, and others which attack rocks, there are other plants which are generally called rock plants, though they behave quite differently, and establish their roots in cracks or crevices of the rocks. Such cracks are full of good soil, for the wind blows decayed leaves and dust into them, and the roots are always burrowing into, eating into, and shattering the rocks. Most of them have a circle of leaves which are pressed flat to the ground. Thus they escape the violent winds and storms always common on such crags and precipices. The flowers, however, supported on tough, strong, and flexible stalks, sway freely to and fro in the wind, and can be seen by insects a long way off.

These rock plants are of some importance as stonebreakers and pioneers in a very interesting process. Wherever a cliff or precipice of stone is exposed, it is "weathered." Water gets into the cracks and freezes in winter. But when water is frozen it expands, and as this happens to the water in the crevices and cracks of rocks, pieces of rock are shivered and broken off. Besides frost and wind and rain, these rock plants help to attack the cliff. Their roots get into the crevices, and there widen and expand, tearing off great slabs and splinters of rock which fall down to the foot of the cliff. Down below plants are every year growing over and

covering up with green these bare fragments and splinters. A considerable amount falls down every year, so that the ground is always being raised up below the precipice. At the brow or edge above the precipice, there is also always a loss of rock and stone every year. Every year the bare rock exposed becomes smaller and smaller, until eventually a steep, green, grass-covered slope covers over the entire site of that precipice.

Moreover, this is not by any means all that plants do in the way of changing the scenery of the country. Look at the outline of the hills in any part of Great Britain except in the broken, jagged, rocky mountain ranges of Scotland and Wales and a few other places. Everywhere there are smooth, flowing, gently undulating rises and falls. No sharp, abrupt descents break these graceful sweeping curves. If you compare the scenery of a cañon in the rainless deserts of Western America, the contrast is very striking. There the sides of the valleys are steep cliffs; it is harsh and precipitous. It is this green covering of plants which makes the difference. The rain that falls is not allowed to cut out ragged ravines; it is intercepted and soaks into the grasses, which so keep a smooth, gentle outline over hill and valley. If you notice the effect of a heavy shower of rain on a road or bare earth, you will see how soon tiny valleys and cañons and beds of streamlets are cut out. But on the green fields beside the road, there is no change in the surface at all. It seems to be quite unaffected by the heaviest storm of rain.

MAKING FOUR-LEAVED CLOVERS

By Eugene P. Lyle, Jr.

THE manner in which Professor De Vries developed his four-leaf variety of clover, illustrates his system of experimenting. Hunting for four-leaved clovers is a familiar occupation. In the fields and lawns they are to be found. A single plant among a host will have several such leaves. They are quite rare, and may be called monstrosities. At least, they are not the regular thing, and hence may be considered as emblematic of good luck. Near Amsterdam, in 1886, Professor De Vries found a plant bearing six or seven four-leaved clovers. This he set out anew in his garden, where it did not bear seeds till 1889. These he sowed, and since then he has had a new generation each year. Each time he chose his seeds from one fourth of the best plants; that is, from those which had the most four and five-leaved clovers. It was the third generation, however, in 1891, that began to be rich in the desired forms of leaves, but only with four and five leaflets, and these only in the adult plants. Still, during August and September of the same year, he remarked a very few with seven leaflets. At this point he reduced his selection (or choosing his seeds from the best specimens) to a severe standard. That is, he chose for progenitors only those plants which had two thirds of all their leaves with four or more leaflets.

Meantime he had discovered a curious fact, which

much simplified his selecting from then on. In sowing clover you may observe that the first leaf of each young plant has but one leaflet, and that the second and subsequent leaves have regularly three leaflets. But in his variety some of the young plants made the very first leaf compound; that is, with two and three leaflets. This knowledge enabled him to make his selections much more quickly. He had only to choose the young clovers with compound leaves, and transplant them from his glasshouse into his garden, leaving the others to perish. Thus he did not need so many hundreds of individuals as before, though each year he still selected some thousands of seedlings from their sowing pots. In 1894 the new variety of clover had come into existence. Of this crop, nearly all the young plants had their first leaf compound, and all of them, with few exceptions, were five-leaved. In among the five-leaved there were some with four and three, and others with six and seven leaflets. He saw none, however, with more than seven. Each year he can pick four-leaved clovers at will for mementoes, and, as he says, they have brought him good luck. The five-leaved clovers, however, are now the normal product. Providing that a rich soil and good culture be maintained, he holds that his five-leaved clover will keep constant, that is, it will not go back to the three-leaved. Such being the case, the cultivation of this new variety should have a high value over the ordinary clover, not only as "cow grass," but as a more energetic enricher of the soil.

A WALK ON THE BOTTOM OF THE SEA

(*Abridged*)

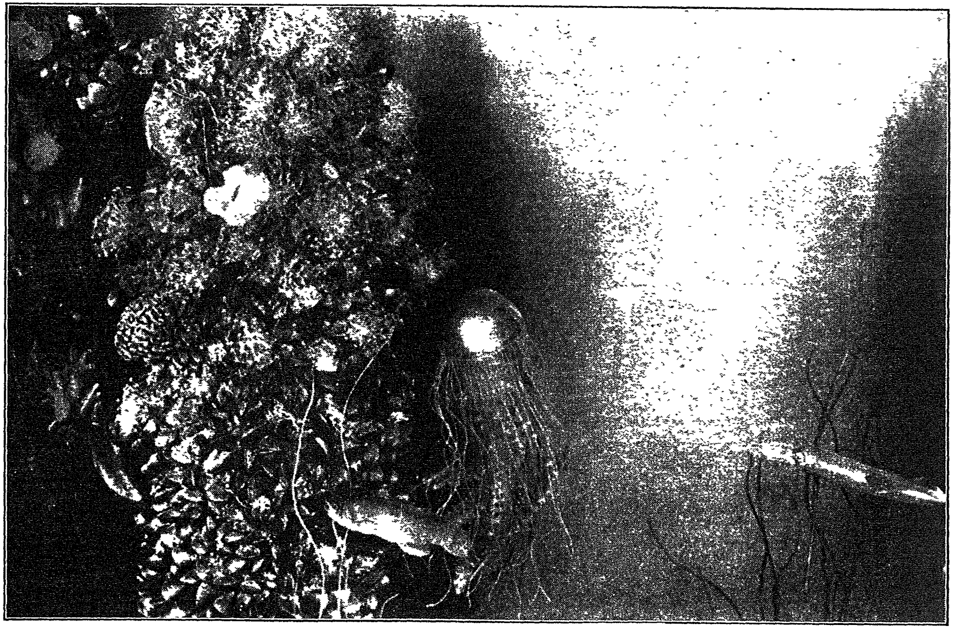
By Alexander Winchell

WE go down like bathers into the sea. We traverse the borders where the brown, belted kelp sways to and fro in graceful curves. We get beyond the slope of stony bottom to the smooth sand. We come to the gardens of the rosy-tinted sea mosses, and startle the bluefish and halibut in their safe seclusion. A moonlight gleam is here, and the water also takes on the chill of evening. We pass on, and attain a depth of half a mile. Our feet press into the finer sediments derived from the land — the dust of other "continents to be." The twilight has faded into a deep shade. The creatures of the sea swarm curiously about us, then flee in terror from our presence. We feel the gentle movement of "a river in the ocean," but the surface disturbances do not reach even to this depth. A change of climate impresses itself on our sensations. The water where we started in had a temperature of sixty degrees — here it is forty. But we press on. We descend to the depth of a mile under the sea. The curiously gazing species of the shallower water appear no more. Their home is the zone which now stretches above our heads. The green and rose sea mosses never venture here. We are in total darkness;

here are only stony, white calcareous algæ and siliceous diatoms of microscopic minuteness.

We pause to contemplate the awful stillness of the submarine realm; and feel our slimy path down to the deeper profound. Above us now float two miles of black sea. Any surface fish brought down here perishes from the effect of enormous pressure, if possessing an air bladder. If it have none, the fish becomes torpid, and finally dies. We are here, probably miles from the shore — that varies with the steepness of the slope. The sediments which the rivers have brought to the ocean have mostly been deposited between our starting point and this. But here still are some of the finest particles contributed by the land — slime from Louisiana, from the Rocky Mountains, from our native town. Will these far-brought and commingled atoms ever see daylight again?

We are standing on the border of the vast abyss which extends over half the area of the earth. It is an undulating, silent desert. No diversity of mountain and valley, cliff and gorge exists. We have read of submarine cliffs and plateaus, but these are known only in the shallower ocean; they are features of the continental slope. By a gentle grade the bottom descends to a depth of five miles. Over all this dread waste, no rocks rise above the bed of slime. No fragments of crystalline rocks have been brought up by the dredge. A thousand miles away the bottom has been burst through by an internal force, and lavas have heaped themselves up to the height of a mile or two, or even to the actual surface; but no upheaval has brought to light from the abysmal floor any trace of



UNDER-SEA LIFE

those hard crystalline rocks of which our boulders are formed. There is no evidence that such rocks were ever produced in that situation.

The pressure on us in this abysmal region is four or five tons to every square inch. The water is ice cold everywhere. The darkness, absolute and palpable. We turn our eyes upward with a painful longing for the light. Only the black ceiling appears. Two miles above us is the sunny sea, where all the blue of a genial sky beams down. There float the ships in summer calm upon a "painted ocean" or tossed and rent by the winter tempest. No sunlight ever penetrates this gloom. No sunrise, or noonday or sunset is ever known. Not even the crash of thunders or the roar of tempests can be heard.

When we crossed the borders of this dark and silent abyss, our feet sank in a white pasty slime which has been designated "globigerina ooze." The dredges of the Challenger and the Albatross have been down here, hung by a piano wire over the stern of the vessel, and samples of this ooze have been studied. We find it composed chiefly of microscopic dead shells called foraminifera, together with others called pteropods. The little creatures which formed the shells do not live here; they dwell in calm zones of water far above. When the animal ceases to live, its tiny house sinks down into this dark world. And thus, as the ages roll by, the fine chalky rain slowly accumulates upon the bottom. When this ooze is dried and hardened, it resembles the chalk of Europe; and when that is microscopically examined, we find in it the same little foraminifera. There are im-

portant geological facts, which, though they come out of an abyss of darkness, throw a vivid light on equally dark chapters of the world's long-past history.

We have groped our way down three and four miles beneath daylight. A sort of ooze still overspreads the bottom; but it is not the globigerina and pteropod ooze. It is a fine rusty clay. But the white shells are not wanting because the tiny creatures which secrete them are not overhead. They swarm there as elsewhere, far from land with other pelagic forms. But the fragile matter of the shell is dissolved before it reaches this great depth. Only the aluminous and insoluble constituent reaches the bottom. This clay ooze possesses other interest. Disseminated through it are minute crystals of such minerals as escape through the throats of volcanoes into the upper air. Here are the dust particles which have imparted a ruddy glow to many a past sunset. Once the source of the roseate glory of the twilight hour, they lie now, in impenetrable darkness and the repose of death. How changed the fortune of the little particle! It floated for months in the upper thin air, borne hither by the simoon, thither by the anti-trades, hurled in the vortex of a cyclone, and precipitated in mid-ocean by a down-falling mass of vapor. Then, perhaps, seized by the waves, and rocked and beaten at the surface till it reached a zone of calm, it began its silent descent into the dark world where it is destined to rest undisturbed for centuries.

Here too is cosmic dust. The seeds of worlds have been sprinkled through space, and some of them have been planted in the soil of this abyss. These minute globules

of magnetic iron were sparks emitted from a burning meteor. The meteor was a small mass or particle of material stuff coursing swiftly through the cold interplanetary spaces. It pierced the atmosphere of the earth; the friction resulting ignited the meteor, and for a brief moment it painted a fiery streak in its flight, when all had been transformed to ashy particles which floated in the air like volcanic dust, until it found, at last, a resting-place in the cold bed of the Atlantic. The particle might have swept on through space, as many of its companions did, until it became part of a glowing comet. Perhaps it once shone in a star — now it is dead for a cycle of years. It is an impressive thought that here, in this rayless night, we find the black ruins of a star.

We still stand wondering over the scene which surrounds us. How oppressive is this silence. How welcome would be the cheerful chirp of the sparrow. Even the piping of the hated mosquito would break the eternal monotony. A chill, which is more than icy, pierces us to the marrow. Sometimes, as we grope through the Egyptian gloom, we kick the bones of aquatic creatures which have perished in the water above us. Here are teeth of sharks and ear-bones of whales which have lain during geologic ages.

But there is indeed life here. Sparse, quaint life; and the species resemble creatures which lived in the earlier ages of the world, or creatures which have undergone but a part of their development — crude, uncouth, and alien to the modern world. Here are crinoids, or stone lilies, which in all other waters have perished from the

earth — save one species long known in the Caribbean Sea. From the deep waters off the coasts of Florida and Norway comes up with other forms, rhizocrinus, a genus which disappeared from shallow seas unknown millions of years ago; but here, where nothing changes, it has perpetuated its existence through half the history of the world.

Still more startling in their grotesqueness are some of the fishes which lie here more than half buried in the mud. Here is one fashioned like a scoop-net. The long, slender body is the handle, and the net is an enormous pouch under the chin, which would take in the whole of the body three times over. Another hangs like an open wide-mouthed meal-bag. In this case also, the bag hangs suspended from the part where the throat should be. The diminutive body is noticed as an appendage attached to the back side of the bag. It is known by the fins. Four of these bodies might be contained in one pouch. A different, but equally erratic form brandishes an attenuated body like a whip-lash appended to an enormous head, exposing an eye which is nearly half its own diameter. Still again, we note a shark-like form, with enormous gape and horrid teeth, having a range of spines along each side of the slender body, above and below, and, most curious of all, a long, thread-like organ depending from beneath the chin, with a tassel-like tentacle bearing structures for feeling, at the end. But see! somebody is here with a lantern. How sleepily the light gleams in the darkness. There is no fire in it. It is an animated lantern without a flame. It is another strange fish. It is phosphorescence which gleams mildly

from his shiny sides. Still another lantern-bearing fish. Here are luminous plates beneath the eyes; behind them, in a cavity, retinal tissue, as if these structures were planned for eyes; but they are not eyes. Real eyes are present. We discover, then, faint relief from the palpable darkness in which we have groped.

But our task is done, our curiosity is gratified; we have glimpsed the underworld. Let us now ascend to the light of the upper world.

WHAT BACTERIA ARE

(*Abridged*)

By T. Mitchell Prudden

THERE is a great group of lowly plants, so small as to be quite invisible to the naked eye, and which until within a few years have been entirely unknown to man. These are the bacteria. So small are the bacteria, and so simple in their structure and activities, that it has not been an easy task for scientific men to decide whether they belonged among animals or plants. It is now definitely settled, however, that they are plants.

The bacteria vary a good deal in shape, but in general they are either like a billiard ball or an egg; or rod-shaped, like a lead pencil; or spiral-shaped, like a cork-screw. One of the most common of the bacteria is a little rod, so small that if you were to put fifteen hundred of them end to end, the line would scarcely reach across the head of an ordinary pin. If you look at them with a magnifying power so great that, if it could be applied to him, it would make a man look about four times as big as Mount Washington, they do not look larger than this. We can make out, however, that they are made up of a slightly granular material surrounded by a somewhat denser envelope.

The bacteria appear under the microscope as pale translucent bodies, and the student usually finds it necessary, in order to see their outlines distinctly, to stain

them with some one of the aniline dyes, — red, blue, or violet, — when they become very distinct.

When they are alive and suspended in fluids many of the rod-like and spiral bacteria can perform the most elaborate and astonishing series of movements. They swim slowly, they turn about, they roll over, they wriggle, dart forward, retreat, bang against one another, rest awhile, sway to and fro, plunge off again, and so on through varying phases of movement until the head swims and the eye tires in following them. This movement, in some of the bacteria at least, is induced by a little hair-like projection from the end of the organism, which vibrates rapidly to and fro. It is very difficult to see these little projections or cilia, even with the most powerful microscopes, but notwithstanding this, they have actually been photographed.

Warmth, moisture, oxygen, and a certain amount of organic matter are the simple conditions which are required for their activities.

When the conditions are favorable they may increase in number to a degree which is limited only by their surroundings. A little constriction appears around one of the bacteria; it grows a little longer, a partition forms across the middle, and in the place of one there are two full-fledged bacteria. These may at once fall apart and each new individual go on dividing as before, or they may cling together, forming threads or chains of varying length, or clumps or masses.

So rapid is this process of reproduction that a single germ by this process of growth and subdivision may give rise to more than sixteen and a half millions of sim-

ilar organisms within twenty-four hours. It has been calculated by an eminent biologist that, if the proper conditions could be maintained, a little rod-like bacterium, which would measure only about a thousandth of an inch in length, multiplying in this way, would in less than five days make a mass which would completely fill as much space as is occupied by all the oceans on the earth's surface, supposing them to have an average depth of one mile.

Let not the timid soul tremble, however, for the principles of the survival of the fittest and the influences of environment have kept our prolific organisms so well in check that the world had grown very old and its favored nursling, man, pretty well along in experience and skill before ever he recognized the existence of these his microscopic contemporaries and possible ancestors.

The struggle for existence goes on where varying forms of bacteria are growing as fiercely as ever it did among more highly organized beings. One race succeeds another, one species adapts itself to the conditions which brought about the extinction of its predecessors. Hardy individuals struggle with their weaker neighbors as the food grows scanty in their microscopic seas, and the weaker goes to the wall.

These bacteria are really very simple forms of cells, and their life expresses itself in certain activities; they move, they nourish themselves and grow, they reproduce their kind. They have the power in carrying on the processes of their own nutrition, when moisture and air are present, of tearing to pieces, in the chemical sense, dead organic material, using up such parts of it as they

need for their own purposes, and setting free the rest in such form as to be available for the use of other living things.

When life ceases to be manifested, in animals and plants alike, [then] if moisture and oxygen and sufficient warmth are present, that process which we know as putrefaction or decay begins, by which the old combinations of matter are broken up and the material set free for the use of other beings. Now just here enter the bacteria. It is they who tear these old organic compounds asunder, use a little of them as may suit their own needs, and turn over the rest to their earth neighbors, who have got higher up the scale of being.

Milk is a most excellent food for many forms of bacteria, and among those which are commonly present in milk is one which causes it to become sour when left to itself. Other forms of bacteria develop those peculiar chemical compounds which give to cheese its special and varying flavors. It is, in fact, a very motley group of chemical substances which these bacteria set free in feeding themselves on nature's waste organic materials. Sometimes they are very bad-smelling gases, sometimes aromatic substances, sometimes they are sweet, sometimes they are sour. But sooner or later they are used by some animal or plant, and so again enter the domain of life. And ever since life emerged from its primal simple forms on the earth, the bacteria have silently gone on tearing the worn-out and useless to pieces, and turning it over in new combinations to other forms of life.

There is an enormous number of different species of

bacteria. They are to be found everywhere in nature. Where putrefaction and decay are going on they are most abundant, but where any form of life can exist they are present, either dry and inactive, or where moisture and food are present, growing and multiplying. In all natural surface waters, in the soil, on all fruits, vegetables, and plants, in the mouths and digestive canals of men and animals, on the skin, wherever dust can go or collect, there are bacteria of various forms in greater or smaller numbers.

So common and abundant are the bacteria that we are constantly taking enormous numbers of them into the system with all of our uncooked food. We should not, however, think of these little organisms which we thus unwittingly consume as things necessarily unclean or unwholesome, for they are only little cells after all, and nearly all the food which we consume, whether animal or vegetable, is made up of masses of cells which are either fit to eat in their natural condition, as in the pulp of fruits, or becomes so by simple cooking or other manipulation.

There is really very little difference so far as wholesomeness is concerned, between the few thousand vegetable cells which we call bacteria which may be clinging to the surface of a grape, and a few hundred vegetable cells of larger size of which the grape itself is composed. There are poisonous vegetables, and there are poisonous bacteria, but we do not shudder as we swallow a mushroom to think what might have happened to us if we had swallowed a poisonous toadstool instead; we see to it that the poisonous are not liable to get in with the

other plants, and then go on enjoying our delicacies like sensible people.

It will thus be seen that the rôle of the bacteria in nature, though humble and silent, is an exceedingly important one. They are indispensable to the continuance of the higher forms of life upon the earth. They may well be called man's invisible friends.

BACTERIA AND WOUNDS

(*Abridged*)

By T. Mitchell Prudden

ONE of the greatest dangers associated with injuries and wounds of the body, whether inflicted by accidents or made by the knife of the surgeon in necessary operations, is the liability to what is known as blood poisoning. So great is this danger, that it has long been known that in war a great many more lives are lost from blood poisoning than by bullets or cannon-balls. The cause of this form of disease, which is so apt to complicate wounds, was for a long time entirely unknown. Then, as these wounds were apt, in blood poisoning, to be foul and bad-smelling, it was concluded that the trouble might be that dirt or filth of some sort got into them and so set up the disease.

What the particular thing was, whether bacteria or something else, which so gained entrance to the body, no one knew. But the surgeons did not wait until they should know all about the cause of the trouble, but began to apply to the wounds such materials as would actually kill germs, or, at any rate, keep the wounds free from putrefactive changes. Carbolic acid, dissolved in water, was found to be efficient in this way in washing the wounds.

Then, as it seemed more and more as if the trouble were due to living germs falling upon the wounds from

the air with the dust, it became the practice, when surgical operations were being done or wounds dressed, to spray carbolic in the air about the operator's hands and over his instruments and upon the wounds, and when the bandages were put on to seal them in tightly, so that no germs could gain access to the wound while the healing went on. All this time the particular species of bacteria which produced the trouble remained entirely unknown; indeed, it was only a hypothesis that the disease was due to germs at all. Now we know that not only blood poisoning but abscesses, erysipelas, and many other less serious inflammations are caused by bacteria. We have found out, furthermore, that there are two particular species which cause the trouble in the great majority of cases.

Now, it has been further found that these two forms of bacteria are quite abundant where people are gathered, mostly in dirty places; sometimes where the healthy, but especially where sick people are crowded together, as in hospitals. They are found in small numbers floating with the dust in the air, where dust lodges, and often in the mouths and on the clothing of the people themselves.

It is thus evident how the wound diseases, such as blood poisoning, can come about, for wherever the dust falls on the open surfaces of the wounds or on anything which comes in contact with them, and the living bacteria lodge, they may, if not destroyed, commence to grow, and not only by the poisonous materials which they form as they grow, interfere with the healing of the wounds, but they may get into the blood and be carried

to various parts of the body, there growing and producing sometimes fatal results.

It is one of the greatest practical triumphs of science in modern times that the surgeon can now so carefully plan out his operations and treatment of wounds, that not only is blood poisoning, as it used to prevail but a few years ago, the greatest rarity among educated and skillful surgeons, but the most extensive operations may now be done, when they are necessary to save life or make it endurable, with very little risk of the frightful dangers which formerly attended such procedures.

Now let us look a little more closely at the way in which these tiny organisms cause inflammation and blood poisoning. Under ordinary conditions, the white blood cells, or leucocytes, as they are called, go circling round the blood vessels along with the red blood cells, or, crawling out of the blood vessels, slowly make their way around in the smaller spaces in the tissues. Exactly what they do under these circumstances we do not know. There is some reason for thinking that they act to some extent as scavengers and when they come across a particle of worn-out or foreign material in the tissues, take it into themselves, and either digest it or carry it back to those parts of the body in which waste material is disposed of.

But let such an injury as an open wound occur, and the whole attitude of these leucocytes changes. They get out of the blood vessels with all speed, in greater or less numbers as the occasion may demand, and gather about the edges of the wound, and after a time, they, together with some other cells of the injured tissue,

change their shape and character, and actually form, with the aid of the blood vessels near by, a mass of new tissues, which replaces that which was lost by the injury, and so permanently binds the edges of the wound together. Sometimes these white blood cells gather in much greater quantities about the wound than is necessary, and then they are thrown off in the form of a material which we call pus.

Now to come back to the bacteria which we are studying. When these bacteria get into the tissues, they may begin to grow, and as they do so they produce a small amount of a poison which we call a ptomaine, and this poison acting injuriously on the tissues where it is formed, the white blood cells gather about it just as they would about a wound. If the bacteria continue to grow and multiply, the white blood cells may accumulate more and more and die, the tissues may break down, and so an abscess may be formed. Sometimes the germs get into the blood and are carried to various parts of the body, and wherever they lodge abscesses may be formed, and this constitutes one of the most dreaded forms of blood poisoning.

Now what do the blood cells accomplish under these circumstances? Many believe, although the matter has not been quite settled yet, that when these bacteria get into the tissues and begin to grow, the arrival of the white blood cells upon the scene signalizes the commencement of a life-and-death struggle between the bacteria and the cells. The cells attempt either to swallow and thus kill and digest the bacteria, or to so closely surround them as to cut off their oxygen and food sup-

ply and so destroy them. The bacteria, on the other hand, so long as they can grow, produce a poison which may kill the white blood cells and break up the other tissues roundabout.

There is much reason for believing that this is what actually occurs: If the conditions are favorable for them, the white blood cells and other cells may get the upper hand of the bacteria and stop their growth or kill them all off and thus avert the danger. If, on the other hand, the cells are not vigorous enough to resist the poison eliminated by the bacteria and themselves succumb to its influence, the way is opened to the spread of the infecting germs.

This is in brief the story of the bacteria which most commonly produce the common inflammations of the tissues, the complications in the healing of wounds, and the varying phases of blood poisoning.

THE MICROBE WHICH COMES INTO MILK

By Harvey Hersey

MILK, fresh from the cow, after standing a few hours in warm weather, becomes sour, as every one knows. The cause of the souring is not in the milk itself. Milk taken from the cow and sealed air-tight, without coming in contact with the air, will not sour. This proves that the cause of souring is not in the milk.

Therefore the something which sours the milk must be either the air, with which the milk comes in contact, or that which comes out of the air into the milk. But it is not the air. Fill a small glass jar with sweet milk. Leave out the cork. Set this jar in a larger glass jar. Seal air-tight the larger jar. Now set the larger jar in a vessel of water on the stove. Boil the water for some time. This sterilizes the air in the larger jar and the milk, too. The sterilized air within the larger jar comes in contact with the sterilized milk in the smaller jar. But the milk will never sour. This shows that it is not the air which sours the milk, but something within the air which comes from the air into the milk.

This something is now well known to be a microbe. The air is thickly populated with this species of microbe. They as naturally like milk as pigs like clover. As soon as the milk comes from the cow, they are attracted into it in great numbers. As soon as there, too, they begin

to grow rapidly and multiply with great rapidity. One may become three thousand in six hours. At this rate, in the same time a thousand become three million, and a million become three billion.

Coming into the milk so rapidly, and, at the same time, multiplying so rapidly, the milk soon becomes densely populated. By the time the milkman's milk gets to one's table, especially in warm weather, a common glass of it will probably contain not less than fifty million of these beings.

These microbes are the cause, and the only cause, of all souring of milk. As soon as in the milk, they subsist on the sugar of the milk, and, by their life processes, convert this sugar into lactic acid; and this acid is the essential element of all sour milk.

It is true that a number of different species of microbes may, by converting its sugar into lactic acid, sour milk. But ordinarily, almost always, only one species is the active cause. Hence, this species has been called "bacillus acidi aceti." But the plain English name, "microbe of milk," is good enough for the present purpose.

It is true that a number of other species occasionally find their way from the air into the milk, but only to do it harm. While they cause the milk to some extent to sour, they work not a little mischief. Some cause the milk to curdle, make it ropy, or even taint it. Others give the milk different hues of color, of blue, red, or yellow. They have no business to meddle with the milk — enemies to the milkman, pure and simple.

The milkman has two means of successfully avoiding these pests. First, cleanliness. Keep the cows clean.

Keep clean the stable. Keep clean the milk cans and other utensils. Second, as soon as the milk is taken from the cow, reduce it to a low temperature, and keep it there until used.

The microbe that simply causes the milk to sour, without any attendant mischief, is the real friend. True, the early souring of the milk may be troublesome to the milkman. But he has an easy remedy. Let him Pasteurize the milk; that is, before distribution, heat it to 165°. This destroys all the germs in the milk which sour it. The milk will then keep sweet practically long enough.

The milk, before used by the customer, should be Pasteurized anyway. After it comes from the cow, several hours usually intervene before it reaches the customer. By this time every glass of it, as we have said, contains millions upon millions of germs. To the adult, or persons in vigorous health, these germs are harmless. But to invalids and young children they are not safe. If, therefore, the milkman Pasteurizes his milk just before distribution to the customer, all danger is avoided. If he does not, then, as soon as the milk is received in the home, it should there be heated to 165°, bottled, corked with sterilized cotton, and kept in a cool place. It will then keep sweet for a long time, and its use will be safe and wholesome.

The natural process of souring milk is a decided benefit. It separates the milk into its four elements, and enables the owner to use each part to best advantage. Every hundred quarts of milk contain eighty quarts of water, five of cheese, four of sugar, and three of butter. The microbes consume the sugar and convert it into

lactic acid. The acid unites with the water, and thus precipitates the cheesy element, while the butter rises to the surface in the shape of cream. The cream is converted into butter, while all the other parts are used as feed for calves, swine, and so on.

It need not be said that the separator now usually takes the place of the microbes, separating the cream from the milk as soon as it comes from the cow. But the practical result in each case is the same.

There is a time in every one's life when he lives wholly on milk. It is the natural food for all young children. It is their best, if not their only, food. It is the natural and only food of all the young of the lower mammals as well. Milk contains more nourishing properties than any other kind of food. The young, therefore, of all mammals, including man, become fat and plump. It is because they feed on the richest and best food in the world.

Hence the production of milk is one of the great industries of the world. The United States keeps about twenty million cows — one cow to every four persons. At the rate of eight quarts of milk per cow per day, the entire flow of milk would be equal to a river of milk six feet deep, twenty-four feet wide, and flowing perpetually at the rate of two hundred and forty feet every twenty-four hours. This river of milk in one way or another, including butter and cheese, constitutes, in some respects, the best and most essential part of the food of more than ninety million people.

Surely, the microbe of milk figures in human life on a large scale.

HOW IDAHO GOT PURE FOOD

(*Abridged*)

By Isaac Russell

SANITARY INSPECTOR JAMES H. WALLIS carried new sanitary standards into the drug stores, the eating houses, the big corporations, the canneries, the slaughter houses, and even the public schools.

Mr. Wallis first met the problem of railroad dining-cars on a trip from his home town — which, on account of his "swat-the-fly" crusade there, has taken on the sobriquet of "Buzzless Boise" — to Salt Lake City, in the neighboring State of Utah.

Tainted chops were served to a merchant of Glenns Ferry, Idaho. He was paying a fancy price for them and up to that moment had never suspected that tainted meat would be served in such luxurious surroundings as prevail on the usual dining-car. A newspaper man on the same train told Mr. Wallis. Mr. Wallis made no disturbance with the waiters, but he went to the kitchen. There he showed his badge and announced that he intended to make an inspection.

He found, first, that the cook was working in a hot little compartment without ventilation. Next he noticed that flies filled the compartment, attracted doubtless by the rancid smell of bad meat. In the ice-boxes he found bad chops, slimy steaks, decaying vegetables. He asked kindly questions of the cook about the reason for

it all, and learned that his particular dining-car was on the home stretch of a long run out of Ogden, Utah, to Huntington, Oregon. The custom, he found, was to stock the car in Ogden and not to restock it again until its return. More than that, there were credit marks for the dining-car conductor who served his goods so sparingly that he always carried the largest amount of surplus. Mr. Wallis took note of the surprising amount of perspiration on the brow of the cook and also of the frying-pans into which it fell. He made a second inspection late at night and noticed the feet of husky negro waiters protruding from blankets laid down over the dining-car tables. Next day he searched for the blankets and found them — stowed away on shelves in the pantry above packages of food that the cook had left open.

Mr. Wallis's manners are the mildest in the world. Neither cook nor waiter nor dining-car conductor even guessed that he was shocked and indignant. Instead of making a display of anger he was thinking out a way to clinch the legal evidence should he be called upon in court to prove what he had seen. He went back to his own car, solicited the help of some friends he found there, and had them look over the whole situation with him.

Then, gently, he approached the dining-car conductor. He received some rather heated suggestions that his jurisdiction was on the other side of a state boundary line some distance to the north.

"All right," he said softly, "I am sorry you look at it that way, because I would have preferred to settle this matter quietly without bringing scandal upon the rail-

road. But I shall now be compelled to exercise that jurisdiction of which you spoke in my own territory."

Now Mr. Wallis had been a newspaper proprietor and he had learned how to make a story into "news." He knew also that there was no policeman so good as the light, properly turned on. So in a few days he had the newspapers handle the story. Mr. Wallis seized all the food, good, bad, and indifferent, in the dining-car lockers.

"But it's perfectly good food," protested the dining-car conductor.

"But it would n't be perfectly good food by the time it reached passengers traveling on your road in this State," replied Mr. Wallis. "How could it be," he added, "when it is carried on the cars so long, and there is no ventilation in the kitchen, and it is bound to be cooked with a liberal sprinkling of perspiration?"

The officials began to protest loudly, and Mr. Wallis began to tell the story of the long runs that the dining-cars made without replenishing the food supply. Some of these officials challenged his veracity and he called upon his friends to tell of their own visit to a dining-car kitchen near the end of the usual run without restocking. The inspector at Ogden, Utah, who supplied the cars, continued its service as it had been, and Mr. Wallis countered by confiscating all the suspicious food on all the dining-cars that came over the border into Idaho. But the passengers began to obtain enlightening data about the actual situation. Women's clubs began to send resolutions to the newspapers.

Then the superintendent of the dining-car service

came to Idaho on a visit of conciliation and fraternity — anything that Mr. Wallis might suggest the road would be only too glad to put into its plan of operation. And Mr. Wallis was ready with suggestions: inner screen doors for the aisles of the dining-cars and screened windows for the cook's compartment — electric fans, two of them, to play upon the cook's brow and thus discourage perspiration; restocking stations at points along the line so near together that fresh food could always be served. Then Mr. Wallis suggested sanitary cots in place of the tables as beds for the waiters, and added that a compartment for the bedding could be built under the floors of the cars so that the bedding need not be stored in the pantry. This plan, too, was agreed on. The final point was that every Pullman porter in the whole train should be equipped with a fly-swatter, so that cars from over state lines might not contribute unwelcome additions to Idaho's very scanty fly supply. To-day, a ride in a Pullman car through Idaho is a perfectly sanitary proceeding.

The proprietors of slaughter houses were another group that thought they could resist the demand for the new sanitation. Mr. Wallis looked the slaughter houses over carefully and privately in the dead of night. He wished to find out where the flies went to roost. In doing this he was stretching the provisions of the law, for the National Pure Food Law provides that only food which in itself is tainted can be condemned. There is no reference to the conditions in the plant in which the food is produced. But Mr. Wallis thought, if he could prove that the flies had a chance to roost on the hung quarters

·esh-killed beef, that would be reason enough why ;laughter houses should be torn down and built over. ɔr several weeks he said nothing while he obtained ence. His final conclusion was that almost every ghter house in the State ought to have the torch ap- l to it and a sanitary, fly-proof building erected in ›lace. His biggest public move was against a meat pany whose plant was located near Boise. Mr. lis had been forewarned that he would strike trouble ·, for he had heard of a combination among mer- ıts to oppose his work in establishing new standards ınitation in commerce. To offset the power of the l which the merchants had raised to defeat him, Mr. lis employed a very simple expedient — he called ɔme women.

'hen he sealed up the plant of the meat company ıuse of the filthy and indescribable conditions that ؛ found at the slaughter house, he was quickly re- ed. Mr. Wallis then gave the "Boise Capital News" e to go ahead and print the story of what Mr. Fred Taylor, one of the paper's youngest reporters, had ıd when he made a secret visit to the company's ıt with Mr. Wallis and two women officers of the .e Humane Society of Idaho.

he story of what they saw was full of ugly and dis- ·eable details, but details that aroused the people. meat concern promptly sued the "Capital News" ibel. Mr. Wallis came to the paper's assistance by rting the truth of the article and referring to others ıcluding the two women — who could give evidence ;s truth. The libel suit was hurried to trial upon the

insistence of the defense, and the jury, at the trial's conclusion, took only time enough to draw up a verdict in reporting that the defendant had won. The meat company had got enough of fighting — it learned that it did not pay, and, after its expensive fight, it went out of business.

Mr. Wallis next moved over to a neighboring town and found a hard working beef, pork, and sheep packer at work on his supply of beeves. Several quarters of dressed meat were hanging in a storage-room — covered with roosting flies. The clothing worn by the men was filthy.

"What are you going to slaughter next?" Mr. Wallis asked in his meekest and least belligerent manner.

"The sheep," replied the meat packer, pointing to a pen in which were a dozen fat sheep.

"You might as well spare yourself the trouble," Mr. Wallis remarked, "because I am going to close your place up and burn all the meat I find in the storage-room. It is n't fit for the market and is n't going to reach the market."

The meat packer had never heard such threats before. He could not believe they were in earnest, so he went ahead and killed, not only the sheep, but a half dozen hogs as well. Next morning Mr. Wallis returned and began to put state seals on the doors of every room in the slaughter house after locking the door shut. He carted off all the carcasses he found in the place and made a bonfire of them. When the proprietor protested, he was told he should have acted upon a tip made out of the kindness of the sanitary inspector's heart the night

before. But to-day he owns a fly-proof slaughter house in which every appointment is of the latest sanitary design, and all the townspeople point to it with pride. Similar results were achieved in Twin Falls, in Grangeville, and two or three score of other cities.

Mr. Wallis soon found as much to keep him busy in the dairies as he had found in the slaughter houses. The farmers laughed at him a little, so he added a camera-squad to his inspecting force. He took pictures of clean farmhouses and clean dairy houses and sent them to the newspapers, and other pictures of dirty dairy houses and dirty farmhouses and sent these to the newspapers, too.

He realized that it would be a long and tedious legal proceeding to force farmers through the courts to keep clean cow barns, whereas the fear of publicity would quickly compel them to do so. The fear of Mr. Wallis's camera-squad became a real one in the rural districts. His pictures of well-kept farms gave ideas to the owners of badly kept farms which they sought to emulate.

For the technical, scientific proof of evil Mr. Wallis could never gain much respect. Instead of capturing samples of milk and taking them to laboratories to have them tested and then commencing court proceedings after the receipt, days later, of highly technical reports, Mr. Wallis made a simple ruling as to milk. It was that any bottle of milk at the bottom of which sediment could be found would be considered unfit for food. He would sally forth in the early mornings, mount the milk wagons from farms that he knew were conducted without regard for cleanliness, and hunt for sediment in the bottles.

If he found this sediment he would tell the driver to turn around and go back to the farm — carrying the sanitary inspector along as a guest. In the presence of the farmer and his wife Mr. Wallis would dump the milk in the pigpen and tell the farmer that his milk would be treated that way every morning until it was free from sediment.

If the farmers disliked him, the women of the State approved his work with emphasis, and nobody arose to dispute Mr. Wallis's ruling. After two years of practice without specific warrant of law, this procedure was given official sanction by the legislature, along with many other reforms that Mr. Wallis had accomplished through the issuance of edicts which had no other backing than the support of the women, a fearless press, and of a constantly enlarging group of enlightened men.

Mr. Wallis found that one of the hardest problems in food reform was to make a pound weigh sixteen ounces. Much of Idaho's butter came in from States that lay to the eastward. A "pound" that weighed more than fifteen ounces was rarely to be found. Mr. Wallis started prosecutions and the dealers replied that they sold their butter by the package and not by the pound. Mr. Wallis appealed to the women again. He asked women in all parts of the State to buy butter — and to obtain receipts showing that their purchase represented so many pounds.

He started prosecutions again, and this time, when the familiar defense of the dealers appeared, he exhibited the receipts from all parts of the State. The dealers found they were fighting a much more formidable

opponent than Mr. Wallis himself — the aroused housewives of the whole State. Mr. Wallis soon afterward was able to ship large wholesale consignments of butter back to the makers, while the dealers in Idaho looked on in meek approval. Butter now comes into Idaho in pound packages of sixteen full ounces.

The local dealers, when ordered to destroy foodstuffs that were in violation of the law, complained that mail-order houses in the East could compete with local merchants without any such harsh restrictions. Mr. Wallis found the freight warehouse through which mail-order goods were distributed. He put his seals on such goods as he found in the warehouse, but the attorneys for the mail-order people immediately threatened injunction proceedings against him on the grounds that he was interfering, as a state officer, with interstate commerce. Mr. Wallis thought things over and took a train for Washington. He told his troubles to the Secretary of Agriculture and received an appointment as a federal inspector under the Pure Food Law, to work without pay. He also received a box full of federal seals. In the dark of the first night after he returned to Idaho, he ripped off all his state seals and put federal seals on the mail-order goods he had seized. He then opened the goods and took samples for bacteriological and chemical analysis.

The mail-order people, of course, sued to make their injunction permanent, but Mr. Wallis replied that they were not dealing with a state inspector at all, but with a representative of the National Government who had found baking powder from Chicago with arsenic in it,

extracts from New York that were sadly misbranded, coffee from Chicago that was mostly chicory, and "burnt peanuts" from Pennsylvania that were coated with a poisonous shellac. The suit was abandoned, but Mr. Wallis went on to tell the people all that he had found in the mail-order goods: turpentine that had been adulterated with kerosene; lemon extract that contained no lemon juice at all; gall-stone cures that were compounded from a mixture of olive oil and Seidlitz powders!

Next he attacked the dangerous patent medicines. He warned the people in bulletins of the danger in headache cures and of the fact that the amount of heart-depressing drugs stated on the label to be in every wafer was often only a fraction of the amount actually contained. He warned the people, too, that manufacturers were evading the purpose of the law by printing on the labels technical chemical terms for poisons of which the public had become suspicious. He warned them, for example, that on four popular brands of headache cure the coal-tar product "acetanilid" was disguised under the technical designation "phenylacetamid," and that "phenacetin," another coal-tar drug against which the people had frequently been warned, was appearing in headache cures under the new name of "acetphenetidin." The people of Idaho had learned to accept Mr. Wallis's word on other things and they heeded his warnings about impure drugs and fake headache remedies, and the druggists commenced stock-taking and cleaning the banned goods off their shelves.

Mr. Wallis made his annual report a document which

the farmer and the merchant alike would read. Handling all sinners without mercy, he still brought forward enough examples of what was good and what was bad practice in every form of commerce to show the buyers what to look for and the sellers what to offer if they would keep public confidence. He illustrated the report with cartoons and photographs until it became a popular book for the fireside rather than a report for state archives.

And by the firesides it is read. Mr. Wallis believes in the public conscience and never tries to move faster than the people will follow him after he has put his case before them. Once the people failed to arouse themselves against a restaurant where he had found boxes of prunes that were worm-eaten and boxes of tea in which spiders had made their nests. He learned that the restaurant was patronized almost entirely by commercial travelers. He carried his case to the commercial travelers at their next state convention and then went with committeemen from that organization through all the restaurants that were patronized by them. The managers might have felt that they could defy Mr. Wallis, but they did not feel that they could defy their own patrons, and they made over their entire plan of kitchen procedure to meet their approval.

A canner in Utah mocked at Mr. Wallis when he told him that his product was too rotten to sell in Idaho. So one day, when Mr. Wallis found some slimy tomatoes in the market in Idaho, he traced them to a wholesale dealer — Mr. Wallis never believes much in punishing the retailers of canned goods — and through the coöp-

eration of this wholesaler he gathered two carloads of the tomatoes from stores in Idaho and condemned them. The canner in Utah went at once to Boise and asked permission to ship them back to Utah to save the cans and boxes. Mr. Wallis figured that the cans and boxes were not worth it, but the canner insisted, so he consented. When he got back to Utah he gave out an interview in which he said that Mr. Wallis had condemned none of his goods. So Mr. Wallis ripped off his state seals of condemnation and put on federal seals, believing that, if he let the goods go back to Utah as agreed, they would be made into catsup and sold again. When the canner received the goods in Ogden he found a federal inspector there to see that every can was actually dumped and destroyed. The canner made a great outcry — but the goods were dumped.

YELLOW FEVER: A PROBLEM SOLVED

By Samuel Hopkins Adams

ALL the world of science now knows that yellow fever is transmitted by the bite of a single species of mosquito and by that agency alone. Patient and perilous experiments have established the responsibility of the little gnat to which is given the name of *stegomyia*, proving it to be the deadliest of all creatures of prey. It kills more human beings every year than the dreaded cobra; more, probably, than all the wild animals of the world put together. Yet so little understood and so difficult to combat has been this tiny man-slayer that those of our cities which are subject to its ravages, up to 1905, have lain supine before its onslaught. Then came the yellow fever outbreak in New Orleans, and the first great American victory over an epidemic.

Eight years before, the mosquito-plague had infected the great, busy, joyous metropolis of the South. Ignorant of the real processes of the infection, New Orleans had fought it blindly, frantically, in an agony of panic, and when at last the frost put an end to the helpless city's plight, she lay spent and prostrate. The yellow fever of 1905 came with a more formidable and unexpected suddenness than that of 1897. It sprang into life like a secret and armed uprising in the midst of the

city, full-fledged and terrible. But there arose against it the trained fighting line of scientific knowledge. Every citizen became a soldier of the public health. And when, long before the plague-killing frost came, the battle was over, New Orleans had triumphed not only in the most brilliant hygienic victory ever achieved in America, but in a principle for which the whole nation owes her a debt of gratitude.

For the foundation of her defenses New Orleans must acknowledge her debt to three young United States Army surgeons. Reed, Carroll, and Lazear established near Havana in 1900 an experiment station to test on human subjects the mosquito theory suggested by Finlay and earlier observers. On the old military principle of leadership, that an officer must not ask his men to go where he himself would not venture, the three surgeons put their own persons to the ordeal. Lazear died, a martyr to humanity, and is remembered by one where the lesser heroes of our Cuban battlefields are acclaimed by thousands. Carroll barely escaped with his life, and Reed, shrinking from no peril which his companions braved, came through unscathed by virtue of some natural immunity, only to die of another illness in the following year. At the price of martyrdom for some of the little squad of volunteers, of patience and peril and suffering for all, it was proved in the utmost detail that only through the bite of an infected mosquito does yellow fever attack the human subject.

How the fever came to New Orleans, or when, no man will ever surely know. From Havana, some think, but the weight of evidence indicates the infected port of

Belize, whence come the United Fruit Company's vessels, bearing fruit, passengers, and sometimes mosquitoes. Study of the passenger lists showed a number of Italian names. That there came to the Italian quarter of New Orleans (which is almost coterminous with the famous "French Quarter") late in May a yellow fever patient; that the mosquitoes which breed in the water barrels and swarm in the houses of the Quarter sucked the infection from the feverish veins to spread it to other men, ten or twelve days later, when the disease had developed in themselves; that these men, bitten by still other mosquitoes, radiated the infection in various circles; and that this ever-widening process continued insidiously until the epidemic had the unsuspecting city in its grip — all this can be mapped out from the form and distribution of the infection when, full-grown, it suddenly sprang, nearly two months after the first case, into the light of public notice.

To understand how the public could have been ignorant of threatening conditions for so long, one must appreciate first the commercial significance to New Orleans of yellow fever. Yellow fever means quarantine which stops traffic at the places of lading. It means a city shut in upon itself; commercial strangulation. It means railroad yards piled with freight; steamship docks choked with accumulated shipments; perishable goods rotting on the piers and in the yards. It is more destructive than a great fire. Business shut off, railroads paralyzed, steamships fast at their piers, a bottomless market, commerce which is rightfully her own diverted to other ports, doors closed, employees dis-

charged, universal distrust and dismay, terror, hunger, and want — all this New Orleans sees written luridly across the yellow flag of pestilence; all this she suffered in the epidemic of '97 from which she had only just rallied. Is it hard to see why the newspapers withheld yellow fever news as long as possible? Is it not in accord with the simple instinct of self-preservation that the powerful financial interests should unite to suppress the dreaded tidings so long as there is a chance of pulling through?

Hope of concealment was foregone on July 23. There were then one hundred probable cases under investigation, and reports of deaths a month back; the infection was known to be in its third stage; alarm among the secretive Italians was widespread; visiting health officers from other States were confirming their suspicions; and the State Board of Health formally announced that the pestilence was present in New Orleans.

The city rang with the wildest rumors. Monstrous exaggerations grew as they spread. The exodus of the terrified began. Men and women hastily gathered their belongings and flocked to the trains before quarantine should pen them in. Panic was in the balance. In that hour of supreme test the city proved itself. All that was best in the citizenship of New Orleans rallied to her from near and far, in courage and indomitable hope. Midsummer is not a particularly pleasant season in the low-lying city. Many persons get away for July and August. Now they hurried back to the stricken town; business and professional men, physicians, clergymen, cotton-growers, bankers, ready to volunteer. The mayor is-

sued a proclamation declaring the situation to be "serious but not dangerous" and calling on the citizens to protect all open water against the mosquitoes. "Kill the mosquitoes" was the battle-cry, and there began the greatest hunt for the smallest game ever undertaken by any community since the Pied Piper fluted the rats out of Hamelin town. The *stegomyia* was, of course, the chief quarry, but all species were put under the ban. "Let the innocent suffer with the guilty," said a speaker at one of the meetings of education. "We know the other mosquitoes don't carry yellow fever, but they're better dead anyhow. Kill them all, and you'll get the right ones as well as the wrong." It was a truly Herodian plan of slaughter.

Among those who hastened back from their vacations to proffer such help as they might give was the Reverend Beverly Warner, rector of the fashionable Trinity Church. A ward heeler whom I met afterward in one of the slums advanced the theory for my consideration that "the Lord made Warner to order for the job." Certainly he was the right man in the right place when the clergyman accepted the general control of the district organizations. These bodies had charge of all the city "above Canal Street," in the effort to confine the infection to the district below Canal Street. At the first meeting of the representatives from the various localities Dr. Warner found himself facing a crowd of the typical "district leaders" of ward politics. Some of his friends had horrid misgivings.

"Those ward heelers," said they, "will take all the money you give them, use just enough of it to make a

showing and to give fat jobs to their followers, and pocket the rest."

Dr. Warner is one of those clergymen, none too common in any church, whose faith in God is paralleled by a faith, almost as strong, in his fellow-men. From the first he assumed that they were single-minded in their loyalty to the city. There was money for the fight, he told them, and it would be handed over to them as they needed it. At the same time the war was likely to be a long and costly one, and they must get all the volunteers possible for the labor and use the money for the necessary supplies. These included oil to kill the mosquito "wigglers" in the water; netting to cover water-tanks and barrels, so that the insect having developed from the "wiggler" could not get out; and sulphur to smother the *stegomyia* in the houses. Immediately there sprang up a spirit of emulation among the leaders, each striving to keep down the expense in his own district. The outcome splendidly justified Dr. Warner's confidence in his fellow-workers, for, at the close of the campaign, every district turned back to him a surplus.

The task to which the organizations set themselves was a peculiarly difficult one. Few cities in the country — probably no other large city — offer such favorable terms to the mosquito as New Orleans. Nearly every house has its private breeding-ground for the little pests. This is because the local water company supplies, at an exorbitant price, a liquid so dirty that it is unfit to drink and unpleasant even to bathe in. Therefore the better class of houses have large cisterns and the poorer class

water-barrels in which the roof drainage is stored for family use. Nothing more convenient and comfortable for the mosquito could be devised; more particularly for the *stegomyia*, as she is a house-haunter, and also exhibits a preference for clear water over muddy. Here, then, right at hand, was a device which, to her instinct, must have seemed providential, a plentiful supply of suitable water within a wing-flap of the house. Pretty nearly every cistern, water-barrel, tub, and other receptacle for storing water in New Orleans was found, when the investigation was on, to harbor the larvæ of the *stegomyia*.

The first move of the district workers was to inspect all premises and note all conditions favorable to the development of the insects. Then arrangements were made either to spread oil over the surface of the water, so that the "wigglers" coming up should be destroyed, or to protect the water by netting. This last method was used for the cisterns. Before it was half done, the supply of wire netting was gone. "Use cheese-cloth temporarily," came the order from headquarters. Thereafter many quarters of the city presented a most eerie appearance, especially at night, each house being haunted by a huge, shrouded ghost, towering beside it.

By the first of August every district outside of the infected region, which was in charge of the federal authorities, was able to announce itself approximately protected. Then the weather allied itself to the epidemic. A terrific night-storm of wind and rain fell upon the city. It tore loose the cheese-cloth and the lighter netting. It overflowed the water-receptacles, carrying

off the safeguarding surface oil. It formed thousands of little pools where the *stegomyia* might drop her eggs. It not only undid the work of toilful days and nights, but it established new conditions of difficulty. That next gloomy morning, when the working leaders crawled down to general headquarters, sick at heart, bedraggled, weary with the desperate, hopeless battle of the night, they found above the office door a bright, new placard bearing a motto for the hour of disaster.

WEAR A SMILE UPON YOUR FACE
AND A FLOWER IN YOUR BUTTON-HOLE

It was like a trumpet-call to the fighting men. In it was embodied the unconquerable spirit of New Orleans under fire. The workers passed beneath the sign, and within found Dr. Warner with a smile on *his* face and a flower in *his* button-hole. None of the atmosphere of defeat was there. It had been a knock-down blow, but the fighter was on his feet again, cool, resourceful, and with unabated courage. That day, the very essence of inspiration went out from headquarters. The call to the work was sounded in every quarter of the city; in banks, in office buildings, on the floor of the exchanges, in the wholesale districts, in the crowded stores, in clubs, in church meetings, in restaurants and saloons, the summons came to every able man to help rebuild the defenses of the city. That day and the next day and for days thereafter, coatless and hatless lawyers and clerks, merchants, doctors, barkeepers, bookkeepers, ministers, and bankers, perching perilously on roof slopes and cistern tops, hammered alternately their unpracticed

fingers and the nails that made sound the netting fortifications of the beleaguered town. And in the evenings they betook themselves, weary, sore, and enthusiastic, to meetings in churches, in halls, in theaters, in schools, in assembly rooms, in every place possible for gatherings, and listened to lectures devoted entirely to the mosquito and the destruction thereof. Thereafter the newsboys in the streets could distinguish the dangerous mosquito at sight, and I have heard a crowd of men in the Boston Club discussing the points of difference between the *stegomyia* and the *anopheles* as casually as if they were talking politics.

Meantime, in the infected district matters were growing steadily worse. The city and state health authorities working together had obviously lost control of the situation below Canal Street. The district organizations, conscientious and unremitting as had been their work, had been unable to prevent an occasional appearance of the disease in the region above Canal Street. Slowly the volunteer army was being beaten back. The time had come to forget local pride and states' rights sentiment, and call on the regulars of the Army of Public Health. An appeal was sent to President Roosevelt, who instantly ordered the Public Health and Marine Hospital Service to take charge of the situation. Surgeon J. H. White, a veteran of many epidemics, was put in command at New Orleans.

It was now literally a fight for life—for the life of the city. The fever had a long start. It was widely disseminated before its existence had become known, and still more widely before its existence was acknowledged and

the city warned. So it was reasonably certain, when the federal authorities assumed control, that there were infected mosquitoes in every part of the French Quarter, that there were probably more than one hundred cases in the stage where mosquitoes biting them would become contaminated, and that there was an unreckonable number of people who, having the disease, had not yet developed it.

Another difficulty was found in the nature of the people among whom the disease had its stronghold. Partly because these aliens are held in suspicion, partly because they do not understand their new environment, and partly by the heritage of centuries of oppression, the low-class Southern Italians are an intensely suspicious people. A superstition is prevalent among them that pestilences are introduced by the Americans, through physicians, to kill off the aliens because of race hatred. Among such a people the task of discovering and tracking infection was one of the utmost difficulty. At first all cases were concealed, and to this is largely due the late discovery of the presence of the disease in the French Quarter.

No sooner had the Marine Hospital Service taken hold, however, than its thorough and scientific inspection at once brought to light a number of unreported cases. In each instance the house where the sick person lay was thoroughly fumigated to kill all mosquitoes, and the patient, unless too ill, removed to a hospital. The New Orleans Terminal Company offered the use of the McDonough Public School, which it owns and which is fairly central to the infected district. The building was

thoroughly renovated; sanitary appliances were put in; the windows were covered with netting, and within a short time the schoolhouse was transformed into as good a hospital, in all practical senses, as if built for the purpose. Dr. Hamilton P. Jones, a young New Orleans physician, an immune, and a veteran of two epidemics, was put in charge. Realizing that the great point to be gained was the confidence and good-will of the Italians, he established a system which, a few years ago, would have been regarded as sheer lunacy. He permitted visitors to come and go freely in the hospital. All that was required of them was that they be thoroughly brushed in a screened anteroom, to remove any mosquitoes that might be clinging to them, and that any packages brought in by them be examined for the same purpose. Not a single case of fever developed from these visits. Presently the Italians came to see that, after all, the American's hospital was the best place for a sick man, and before the epidemic was over they had begun to report cases of their own free will.

All the forces of the Marine Hospital Service were concentrated in a twofold endeavor: first to discover all cases and so dispose of them that they should be guarded against mosquito bites; second, to destroy all mosquitoes. A house-to-house inspection was established with a system of daily reports. Where a case in any way suspicious was found, netting was immediately put over the bed and across the windows. Did it develop into yellow fever, the patient, if able to be moved, was taken to the hospital in a screened ambulance, and the house, having been sealed at doors and windows with gummed

paper, was treated to a thorough sulphur fumigation. Sometimes entire blocks were fumigated "on suspicion," when several cases had appeared near together. Exposed water, even in small receptacles, was carefully protected, and owners of unscreened cisterns were called to a sense of their responsibilities by being haled to a police court and promptly fined. Naturally there was no little resentment and some resistance to the emergency measures; but hygienic law is not unlike martial law, and where it was necessary the authorities controlled with an iron hand.

New Orleans was regarded as the source of all outside infection. That some quarantine measures were proper and necessary is obvious. But reason, justice, and even humanity were disregarded in some localities and by some authorities. Arkansas refused to permit through traffic from infected States, although this does not involve the slightest peril, and Governor Davis would not permit a special train carrying a Marine Hospital surgeon with supplies to pass through a small strip of Arkansas territory on its way to New Orleans. On the other hand, New Orleans kept her doors open to all refugees. Perhaps two hundred refugees from infected towns like Tallulah fled to New Orleans, and something like one hundred cases of fever were brought in from near-by settlements. Yet so competent was the control of the authorities that there was no spread of the infection from the sick refugees, and none of the sound ones took the fever after reaching New Orleans.

Some of the outside quarantine restrictions would have been ludicrous had they not been so serious. At

certain towns guards were on duty at the station with rifles and shotguns, and any unfortunate who dared to open a car window for a little air was immediately "covered," and ordered to "shut that window, and do it quick," notwithstanding that at times trains stood for an hour or more in the full heat of the sun. Famine-stricken refugees could get no food for hundreds of miles. Mississippi refused to accept health certificates from the Marine Hospital Service. Texas established an absolute quarantine. Alabama compelled all passengers to change cars at the border, as if it were the car that carried contagion. Although the transmission of yellow fever in freight is so extremely unlikely that the federal health authorities dismiss it from consideration, freight quarantines were common. A carload of telegraph poles wandered for five weeks from border to border of Arkansas, Texas, and Alabama, only to be rejected by lynx-eyed guards who probably thought that mosquitoes were roosting in them. Greenville, Mississippi, in a sudden fit of self-protection notified the United States Postal authorities that it would receive no unfumigated mail. The department does n't think it worth while to fumigate mail from yellow fever localities, because so few people inclose mosquitoes when writing to friends. Greenville was permitted to go without letters for one week, at the conclusion of which it had a change of heart, and meekly accepted what came to it. Madison Parish, Louisiana, barred out all freight, including drugs! Wesson, Mississippi, reached the limit of precaution by refusing to receive three barrels of carbolic acid. In vain did the shippers offer to coat the

barrels with bichloride of mercury, and put netting over the bungholes so that the mosquitoes which were inside feeding on the carbolic acid could n't escape and devastate the country! Wesson was past all sarcasm; it stolidly declined to accept the consignment.

All this time New Orleans, harassed by the stringent quarantine, half-strangled in its business life, was steadfastly, cheerfully, bravely fighting the good fight. Even when matters looked blackest, there was no sign of public gloom or despair. The newspapers printed all the news, but with calmness and restraint from sensationalism; printed also optimistic editorials; and almost daily instructions how to destroy mosquitoes and to escape infection. Business houses ran at a heavy loss, some of them practically at a standstill, rather than tacitly admit defeat by closing their doors temporarily. I remember particularly one advertisement of a large house, denying, in terms of the most inspiring exasperation, that it had shut up shop or had any idea of shutting up shop for any such insignificant cause as the trifling local epidemic.

Finally the experts began to realize that they were making headway. The figures [of cases] were dropping, not regularly, but with a steady downward tendency. Sporadic cases still appeared, and continued to appear, for a month. There was no cessation of watchfulness in the infected district. But it was only the last chance firing of a defeated enemy. New Orleans had fought the greatest fight for the public health on record; she had won as complete a victory as ever was won over an epidemic; for when the pestilence was routed, frost, the

only victor heretofore, was still nearly two months away. One other mark of honor must be credited to the city's account: the final establishing beyond all doubting and by the test of fire and blood, of the dogma that the mosquito and the mosquito alone transmits yellow fever from man to man.

DOING BUSINESS BY THE WEATHER MAP

(*Abridged*)

By Allan P. Ames

A YOUNG contractor, recently graduated from street-paving jobs into the broader field of reclamation work, went into bankruptcy, and his creditors met to learn what they could save from the wreck. Wishing to get the full benefit of an expensive lesson, they inquired carefully into the causes of the disaster; and most of them carried away the consoling notion that it was an exaggerated case of hard luck which discredited neither their own good judgment nor the honesty and ability of the bankrupt. A shrewd but kindly old banker, who held fifty thousand dollars' worth of the contractor's worthless paper, summed up the situation as follows: —

"Jim's a genius at handling men and a wizard at figures; but when you have to outguess old Boreas about the weather you need capital enough to cover up an occasional mistake."

Rain and cold weather had conspired to ruin the contractor, and had done their work thoroughly. He had figured to the last decimal the number of cubic yards of earth and rock he had to excavate and just how much cement was needed for his dams and reservoirs and just what it would cost to transport men and machinery from

the nearest markets and to house and feed a regiment for a year or more in a sparsely settled region. It was a big conservation and irrigation project in a Western State. The work was more than half finished and the results thus far had justified his calculations, when the elements turned loose and in two weeks wiped out first his paper profits, then his small reserve, and finally his really excellent credit. A sudden freeze spoiled ten thousand dollars' worth of fresh cement work; the rains washed out his tramways and started a landslide that filled his deepest cut; a meandering little stream rose overnight in the hills of the adjoining State and swept away the foundations of his principal dam. About all that was left for his creditors was a couple of steam shovels, some rolling-stock, a stack of hand tools, and a few thousand bags of cement.

This is a picturesque kind of hard luck, popular with writers of stirring tales in which the heavy villainy is left to Mother Nature. Now, as a matter of fact, Nature is not the treacherous virago she is so often described. Year in and year out she follows a fairly reliable routine; and when she indulges one of her rare whims she gives due warning. If the unfortunate contractor, before submitting his bid, had consulted the records of the United States Weather Bureau, he might have learned the average date of the first hard frost in that region during the last ten years, and confined his cement work to a safer period. The same records would have warned him when to look out for excessive rainfall; and the nearest governmental observer could have told him that it had been raining hard in the neighboring

hills for three days before the floods descended upon him.

This is not an isolated case. Examples of similar ignorance and neglect can be multiplied, not only in outdoor work but in nearly every branch of commerce and industry. But there is more to learn from the experiences of men who realize the practical value of the service and have coined forecasts and temperatures and precipitation records into profits.

The days of skepticism regarding the reliability of the Weather Bureau are past. If the forecast in the morning paper indicates rain, most of us carry umbrellas and mackintoshes when we leave home. The average citizen's appreciation of the weather service ends here — with its ministration to his personal convenience and comfort. The more important application of the Weather Bureau's work to business is not so well known.

Study of the weather reports from day to day helped an Iowa man to build up one of the largest wholesale fruit businesses in the Middle West. His method was simple. Most small fruits, and particularly strawberries and raspberries, spoil easily when picked wet. This man shifted his orders so as to avoid buying from sections subjected to recent rains. A result was that he gained a reputation throughout the trade for the excellent quality of his stock.

One day this dealer roused the curiosity of the local weather observer by a telephone inquiry about the weather prospects in the grape belt of western New York which, at that season, supplied a large part of the

demand from the territory just west of the Mississippi River.

"Rain," was the answer. "It's going to rain there to-morrow and probably the day after."

A week or two later the observer met the merchant and asked what use he made of the information.

"It was worth to me," replied the fruit man, "about two hundred dollars. You see, grapes can't be picked in wet weather; so I knew if it was going to rain out there, grapes would be scarce here. As soon as I got your answer I ordered a double shipment — two cars instead of one. It rained in New York for three days running, and the price of grapes here rose to a figure that let me sell my shipment at a fine profit. The only mistake I made was in not ordering four cars instead of two."

In his last annual report, the chief of the Weather Bureau asserts that eighty-five per cent of the governmental forecasts prove correct, and adds that this is a conservative estimate. The popular reputation of the bureau may rest upon its success in discounting the future, but business owes quite as much to the painstaking, scientific care with which the service collects a complete record of daily weather changes throughout the country — after the changes have taken place. These records have accumulated now for a sufficient number of years to furnish fairly reliable averages, actuarial tables of weather risks, which are bound to increase in accuracy and value as time goes on.

Comparatively few industrial concerns thus far have taken advantage of this phase of the Weather Bureau's

work; but the Government's meteorologists believe that the time is not far off when its importance will be universally appreciated. One of the first big corporations to recognize its value was the United States Rubber Company, which deals in rubber boots and shoes and waterproof garments and rubber tires. Accountants from the office of this company spent a week recently copying records at the office of the New York Weather Bureau. From these figures, tables have been prepared which show the average temperature and precipitation during the last ten years for every month of the year in the various districts into which the country has been divided by the sales department. By this means the company expects to multiply the efficiency of its forces, conserve the energies of its salesmen, and furnish a timely guide for its local advertising.

Another concern which manufactures raincoats and has agents in every State of the Union has just prepared, from the New York Bureau's rain records, tables which show for its different districts not the amount of precipitation, but the average number of days when rain fell during each month. The theory in this case was that raincoats are worn just as much when it sprinkles as when it pours.

The sales manager of a big hardware firm, whose salesmen cover the continent, has a file of the Government's daily weather reports always at his elbow. If one salesman writes from southern Minnesota that his poor showing for the month was due to unusually rough weather, the sales manager checks up his excuses and perhaps the records point out to the manager something

that the salesman overlooked — for example, that his territory has enjoyed a long spell of unusually good growing weather which, a month or two hence, promises an extraordinary demand for certain harvesting tools; or that weather conditions have been hopelessly against him, but so propitious to the salesman of the territory in the adjoining State that he has n't been able to cover his field. In that case the first salesman gets a telegram to abandon his own territory for a time and to go and help his associate.

The governmental records do not stop at summarizing temperatures and precipitation. They show the mean and the maximum and minimum temperatures for every month and year at a large number of stations scattered throughout the country. The average temperatures at eight o'clock in the morning and at eight o'clock at night, the number of days in each month when the mercury registered below freezing or above ninety degrees Fahrenheit, the monthly percentage of humidity, the monthly average of wind pressure, the maximum and minimum velocities of the wind and its prevailing direction, the number of days each month when it reached a gale of forty miles an hour and the direction at the time of its greatest velocity, the monthly number of thunder storms, the atmospheric pressure, means and extremes, and the sunshine record — the number of hours each month when the sun shone.

All these statistics find practical uses. Take the sunshine record! A housekeeper is filled with indignation by an abnormally heavy gas bill. She compares the charge with that of the preceding month and then, if she

is a careful manager who keeps her receipts, with the account of the same month a year ago, and proves to her own satisfaction that she has been overcharged. With these old bills as evidence she goes to the gas company's office to demand an adjustment.

"How is it possible," she inquires, "that we burned six dollars' worth of gas last month, when just a year ago in the same house, with the same number of occupants, our bill was two dollars less?"

Occasionally, of course, the meter is at fault, and the consumer has a just grievance; but generally the company can explain the discrepancy in a way that leaves no ground for dispute. The complaint clerk reaches for his weather records; probably he has had to answer similar complaints many times since the monthly bills were mailed.

"Madame," he answers, "the last month had an unusual number of rainy or cloudy days on which you had to use your lights early. The same month a year ago was favored by an unusual amount of sunshine. According to the Government's figures, last month had only 166 hours of sunshine compared with 250 hours a year ago. That, you see, represents just about the difference in these bills."

Last fall the Weather Bureau was asked to tell the average dates when the ground froze in each part of the country. The request came from one of the largest manufacturers of metal fences in the world. By reference to its records, the bureau was able to furnish this concern with information which served as a basis for its selling campaigns, and through which the company

expects to eliminate an immense amount of waste motion.

To the general public the Weather Bureau is best known through its daily forecasts and weather maps. Nearly ninety thousand of these forecasts are mailed every day, and the telephone makes this information available, within an hour from the time of issue, to five million persons. This mail and telephone service is distinct from the distribution effected through the press associations and the daily papers. In many rural sections the telephone companies facilitate the dissemination of this information by connecting, at a stated time every day, all the subscribers on a certain line with a central office, so that all points get the forecast simultaneously. Fifteen thousand farmers receive this daily telephone bulletin in Ohio alone.

Every day four thousand forecast cards and two thousand weather maps go out from the New York City Bureau, which is the largest distributing point next to Washington; and this number satisfies barely one tenth of the demand. Two hundred banking, bond, and produce houses in New York City send messengers every morning to bring them the weather maps as soon as they come from the printing machine of the local bureau. In the office of J. P. Morgan & Co. a high-salaried employee devotes most of his time to studying these reports in their relation to the far-reaching interests of that banking firm.

The multitude of humbler services performed by the Weather Bureau in a great city is illustrated by the flood of telephone queries that reach the New York office.

Answering these takes all the time of one man; on some days they number seven or eight hundred. Most of them come from persons who have practical uses for the information and need it earlier than it would reach them throught the regular channels.

One of the first calls of the day, perhaps, comes from the local plant of the largest yeast company in the country. The manager asks what the temperature will be at eleven o'clock the following morning. The science or meteorology could be put to no severer test; and the efficiency of the Government's experts is demonstrated by the fact that their answers, except on rare occasions, prove correct to within one or two degrees. The information plays an important part in the process of ripening the yeast.

The manager of a restaurant which feeds three thousand persons a day asks for an early forecast before ordering his supplies for the next twenty-four hours. If the prediction is rain or snow he curtails, because inclement weather reduces the daily number of his patrons by from four to five hundred. If a hot spell is coming, he doubles his orders for green vegetables and ices and cooling drinks; in expectation of a cold wave he plunges on meats and baked beans and hearty soups.

The head of a concern that operates sixteen haberdashery stores throughout the city telephones for information which enables him to regulate his window displays and his daily advertisements. Obviously, a cold snap must not catch his stores with their show windows full of summer garments, nor must a season of dry, hot weather set in just after he has devoted several hun-

dred dollars' worth of newspaper space to the merits of his raincoats and umbrellas.

During the berry season the retail grocer who understands his business studies the weather forecasts with unusual attention. It is a season he dreads. He must handle small fruits to keep the good will of his customers, but his losses from berries that spoil frequently wipe out his profits. Strawberries, in particular, are so perishable that few customers will buy them without a personal inspection. For this reason a rainy day which keeps the housewife indoors generally cuts the strawberry sales in two; and if the dealer has not taken warning from the previous day's forecast and reduced his purchases from the commission house, he finds himself with an overstock which, not infrequently, he is obliged to sell below cost or dump into his garbage cans.

The shippers of perishable goods were among the first to appreciate the practical importance of the Weather Bureau. Merchandise may be several days in transit, and the necessity of preparing for weather conditions that may be encountered during a long journey calls for expert knowledge of meteorological geography. The bureau will furnish the records and forecasts, but the shipper must work out each separate problem for himself. It is not the mean temperature he must guard against, but the extremes. In this he is guided mainly by the data which the bureau has been accumulating for the last twenty or thirty years. He determines the danger points and then consults the special long-distance forecasts which the weather men in his home town will figure out for him. For example, in preparing to send a

carload of bananas from New York to Buffalo during the winter, the shipper would ascertain what the lowest temperatures were likely to be in the Pocono Mountains or the Mohawk Valley, depending upon the route chosen.

The 4th of March, 1909, brought a snowstorm that was memorable not for human suffering nor property loss, but for an unprecedented prostration of wire communication over the territory east of the Mississippi River. President Taft was being inaugurated in Washington and not a newspaper in the country that elected him was able to get the news. Without doubt it was one of the most dismal inauguration days in the history of the nation; but nowhere was its gloom darker than in the lofty æries occupied by the man of the Weather Service. For the bureau had failed to give adequate warning of what, while it lasted, seemed almost a national catastrophe. Yet this mistake proved a piece of good fortune, not only for the bureau, but for thousands of persons who, up to that time, had not appreciated the practical importance of its work. It started a controversy which gave the service plenty of wholesome advertising.

This is how it worked out: Before several million newspaper readers had time to forget the inconvenience of that short gap in the news of the world, a magazine writer took the inauguration day storm as his text and constructed an argument to prove that the Weather Bureau was not giving the people of the United States adequate return for the million and a half they spent every year to maintain it. The article attracted wide attention, and naturally the weather men were disturbed.

They knew that it presented a false conclusion based on a trifling percentage of exaggerated failures; so they set about contradicting it with an array of facts and figures.

The evidence they collected surprised even the Bureau's best friends. All over the country boards of trade adopted laudatory resolutions; farmers and shippers and merchants and engineers and contractors wrote to the papers declaring the value of the service in terms of hard cash. California sent word that by taking advantage of a single cold wave warning the citrus fruit growers of that State had saved $14,000,000. Shipowners testified that the storm warnings displayed at three hundred points along the seacoast and on the Great Lakes had saved lives and property beyond estimate. Warnings of one hurricane that swept in from the West Indies had detained in port vessels valued with their cargoes at more than $30,000,000, a large percentage of which must surely have been lost if the storm had caught them far from shelter. Flood warnings along the Mississippi in a single season had saved, according to reliable estimates, property worth $10,000,000. But from a purely financial standpoint even these figures seemed insignificant beside the report that came from the produce dealers of New York City. On the basis of statistics compiled by seventy-five leading commission houses, these dealers declared that the weather warnings of the preceding year had saved five per cent of the perishable produce handled in New York City, a saving valued at $20,000,000. If produce dealers throughout the country had given to the weather forecasts the same attention they received in New York, a conservative estimate on

this basis valued the services of the bureau to this one industry at $100,000,000.

When the Government's meteorologists recovered from the surprise of this overwhelming vindication, they gathered these resolutions and reports and newspaper editorials in a printed pamphlet and sent a copy to the Committee on Agriculture of the House of Representatives, which was preparing to investigate the Weather Bureau in response to what its members conceived to be a popular demand. The investigation never was started, but the Committee on Agriculture a few days later recommended an increase in the annual appropriation for the work of the bureau.

LIQUID AIR

By Ray Stannard Baker

LIQUID air is a clear, sparkling substance resembling water, but it is so cold that it boils on ice and freezes alcohol and mercury. Although fluid, it is not wet to the touch, but a drop of it on a man's hand burns like a white-hot iron. It may be dipped up and poured about like so much water, but if it is confined, it explodes more terribly than nitroglycerine, and when left standing in the open air for a few minutes it vanishes in a cold gray mist, leaving behind only a bit of white frost.

Charles E. Tripler, of New York City, has invented a machine for producing this most marvelous of liquids in large quantities, and he has found many curious and wonderful uses to which it may be put. He predicts that it may sometime rival electricity in the variety of its adaptations; he tells how it will be used to cool hospitals and hotels, cauterize wounds, drive the machinery of submarine boats, flying machines, and horseless carriages, furnish ammunition for military purposes, and perform many other mechanical wonders.

Until twenty years ago scientists believed that air was a permanent gas — that it never would be anything but a gas. They had tried compressing it under thousands of pounds of pressure to the square inch, they had tried heating it in the hottest furnaces, and cooling it to the

greatest known depths of chemical cold, but it remained air — a gas. One day in 1878 Raoul Pictet submitted oxygen, of which air is largely composed, to enormous pressure combined with intense cold. The result was a few precious drops of a clear bluish liquid that bubbled violently for a few seconds and then passed away in a cold white mist. Pictet had proved that oxygen was not really a permanent gas, but merely the vapor of a mineral, as steam is the vapor of ice. Fifteen years later Olzewski, a Pole of Warsaw, succeeded in liquefying nitrogen, the other constituent of air. About the same time, Professor James Dewar, of England, exploring independently in the region of the North Pole of temperature, not only liquefied oxygen and nitrogen, but produced liquid air in some quantity and then actually froze it into mushy ice — air ice. The first ounce which he made cost more than three thousand dollars. A little later he reduced the cost to five hundred dollars a pint, and the whole scientific world rang with the achievement.

When I visited Mr. Tripler's laboratory I saw five gallons of liquid air poured out like so much water. It was made at the rate of fifty gallons a day, and it cost, perhaps, twenty cents a gallon. Not long ago Mr. Tripler performed some of his experiments before a meeting of distinguished scientists at the American Museum of Natural History. It so happened that among those present was M. Pictet, the "father of liquid air." When he saw the prodigal way in which Mr. Tripler poured out the precious liquid, he rose solemnly and shook Mr. Tripler's hand. "It is a grand

exhibition," he exclaimed in French; "the grandest exhibition I ever have seen."

The principle involved in air liquefaction is exceedingly simple, although its application has sorely puzzled more than one wise man. When air is compressed it gives out its heat. Any one who has inflated a bicycle tire has felt the pump grow warm under his hand. When the pressure is removed and the gas expands, it must take back from somewhere the heat which it gave out; that is, it must produce cold.

At the earliest announcement of the liquefaction of air Mr. Tripler had seen, with the quick imagination of the inventor, its tremendous possibilities as a power-generator, and he began his experiments immediately. After futile efforts to utilize various gases for the production of the necessary cold, it suddenly occurred to Mr. Tripler that air was also a gas. Why not use it for producing cold?

"The idea was so foolishly simple that I could hardly bring myself to try it," he told me, "but I finally fitted up an apparatus, turned on my air and drew it out a liquid."

Mr. Tripler's workroom has more the appearance of a machine shop than a laboratory. It is big and airy, and filled with the busy litter of the inventor. The huge steam boiler and compressor engine in one end of the room strike one at first as oddly disproportionate in size to the other machinery. Apparently there is nothing for all this power — it is a seventy-five horse-power plant — to work upon; it is hard to realize that the engine is drawing its raw material from the very room in

which we are walking and breathing. Indeed, the apparatus where the air is actually liquefied is nothing but a felt and canvas-covered tube about as large around as a small barrel and perhaps fifteen feet high. The lower end is set the height of a man's shoulders above the floor, and there is a little spout below, from which, upon opening a frosty valve, the liquid air may be seen bursting out through a cloud of icy mist. I asked the old engineer who has been with Mr. Tripler for years, what was inside this mysterious swathed tube.

"It's full of pipes," he said.

I asked Mr. Tripler the same question.

"Pipes," was his answer — "pipes and coils with especially constructed valves — that's all there is to it."

So I investigated the pipes. Two sets led back to the compressor engine, and Mr. Tripler explained that they both carried air under a pressure of about twenty-five hundred pounds to the square inch. The heat caused by the compression had been removed by passing the pipes through coolers filled with running water, so that the air entered the liquefier at a temperature of about 50° Fahrenheit.

"One of these pipes contains the air to be liquefied," explained Mr. Tripler; "the other carries the air which is to do the liquefying. By turning this valve at the bottom of the apparatus, I allow the air to escape through a small hole in the second pipe. It rushes out over the first pipe, expanding rapidly, and taking up heat. This process continues until such a degree of cold prevails in the first pipe that the air is liquefied and drips down into a small receptacle at the bottom. Then

all I have to do is to turn a valve and the liquid air pours out, ready for use."

Sometimes the cold in the liquefier becomes so intense that the liquid air actually freezes hard, stopping the pipes. Wonderful as it is to see ice that is made of air, it is not so wonderful as Mr. Tripler's story of the significance of this phenomenon. He tells how at some remote age in the future, all of the atmosphere which we now breathe will fall in drops of liquid, just such as he produces in his laboratory, and great lakes and oceans of air will form on the earth, much resembling the present lakes and oceans of water.

"When the earth grows so cold that the air is liquefied," said Mr. Tripler, "of course all the water on the earth will long ago have been frozen solid. Indeed, it will be as hard as rock crystal, and not unlike that substance in color and texture. After the air is all in the form of lakes or oceans, the cold will continue to increase until they in turn are frozen hard. After that the hydrogen, helium, and possibly some other very light gases, of which we may now have little knowledge, will fall in the form of rain, and then the world will be absolutely dead and inert, frozen as hard as the moon.

"When you come to think of it, we're a good deal nearer the cold end of the thermometer than we are to the hot end. I suppose that once the earth had a temperature equal to that of the sun, say, 10,000° Fahrenheit. It has fallen to an average of about 60° in this latitude; that is, it has lost 9940°. We don't yet know just how cold the absolute cold really is — the final cold, the cold of interstellar space — but Professor Dewar

thinks it is about 461° below zero, Fahrenheit. If it is, we have only a matter of 521° yet to lose, which is small compared with 9940. Still, I don't think we have any cause to worry; it may take a few billion years for the world to reach absolute cold."

Mr. Tripler handles his liquid air with a freedom that is awe-inspiring. He uses a battered saucepan in which to draw it out of the liquefier, and he keeps it in a double iron can, not unlike an ice-cream freezer, covering the top with a wad of coarse felt to keep out as much heat as possible.

"You can handle liquid air with perfect safety," he said; "you can do almost anything with it that you can do with water, except to shut it up tight."

This is not at all surprising when one remembers that a single cubic foot of liquid air contains 748 cubic feet of air at ordinary pressure — a whole hall bedroom full, reduced to the space of a large pail. Its desire to expand, therefore, is something quite irrepressible. But so long as it is left open it simmers contentedly for hours, finally disappearing whence it came. There being no way to confine liquid air in any considerable quantity, its transportation for long distances is therefore an unsolved problem, although Mr. Tripler has sent large cans of it to Boston, Washington, and Philadelphia.

"It is my belief," comments Mr. Tripler, "that there will be little need of transporting it; it can be made quickly and cheaply anywhere on earth."

Liquid air has many curious properties. It is nearly as heavy as water and quite as clear and limpid, although when seen in the open air it is always muffled in

the dense white mist of evaporation which wells up over the edge of the receptacle in which it stands and rolls out along the floor in beautiful billowy clouds. No other substance in the world, unless it be liquid hydrogen, is as cold as liquid air, and yet Mr. Tripler dips his hand fearlessly into a pail of liquid air, but he is careful to withdraw it instantly. The reason is the same that enables the workman to dip his hand into molten lead, the moisture of the human flesh forming a little cushion of vapor which keeps away for a second the effect of the cold or the heat. A few drops held in my hand for an instant felt exactly like a red-hot coal. It does not really burn, of course, but it kills, leaving a little red blister not unlike a burn. For this reason, one of its prospective uses will be for the purpose of cauterization in surgical cases. It is not only a good deal cheaper than the ordinary caustics, but is much more efficient, and its action can be absolutely controlled. Indeed, a well-known surgeon performed a difficult operation on a cancer case with liquid air furnished by Mr. Tripler, and reported the case to be absolutely cured.

It is a curious thing to see liquid air placed in a teapot boiling vigorously on a block of ice, but it must be remembered that ice is nearly as much warmer than liquid air as a stove is warmer than water, so that it makes liquid air boil just as the stove makes water boil. If this same teapot is placed over a gas flame, a thick coating of ice will at once collect on the bottom between the kettle and the blaze, and no amount of heat seems enough to melt it.

Alcohol freezes at so low a temperature — 202° below

zero — that it has been used in thermometers to register all degrees of cold. But it will not measure the fearful cold of liquid air. I saw a cup of liquid air poured into a tumbler partly filled with alcohol. Mr. Tripler stirred the mixture with a glass rod. It boiled violently for a few minutes and then the alcohol thickened up slowly until it looked like maple syrup; then it froze solid, and Mr. Tripler held it up in a long steaming icicle. Mercury is frozen in liquid air until it is as hard as granite. Mr. Tripler made a little pasteboard box the shape of a hammer-head, filled it with mercury, suspended a rod in it for a handle, and then placed it in a pan of liquid air. In a few minutes the mercury was frozen so solid that it could be used for driving nails into a hard-wood block. What would the scientists of twenty-five years ago have said if any one had predicted the use of a mercury hammer for driving nails?

Liquid air freezes other metals just as thoroughly as it freezes mercury. Iron and steel become as brittle as glass. A tin cup which has been filled with liquid air for a few minutes will, if dropped, shatter into a hundred little fragments like thin glass. Copper, gold, and all precious metals, on the other hand, are made more pliable, so that even a thick piece can be bent readily between the fingers.

Not long ago Mr. Tripler took a can of liquid air to the Harlem River, and poured it out on the water in order to see its effects. Small masses of it at once collected in little round balls on the surface of the river, and being so much colder than the water, they froze small cups or boats of ice, in which they began floating

swiftly, bumping up against one another like so many lively water bugs, finally boiling away and disappearing, leaving the miniature ice boats quite still. If a small quantity of liquid air is placed in a tall jar of water, part of the liquid nitrogen, which is lighter than water, will evaporate first, then the liquid oxygen, which is slightly heavier than the water, will sink in beautiful silvery bubbles.

I saw an egg frozen in liquid air. It came out so hard that it took a sharp blow of the hammer to crack it, and the inside of it had the peculiar crystalline appearance of quartz — a kind of mineral egg. At one time in Boston, Mr. Tripler had some of his liquid air with him at a hotel, where he was explaining its wonders to a party of friends. The waiter served a fine beefsteak for dinner, and Mr. Tripler promptly dipped it into the liquid air and then returned it with some show of indignation to the chef. It was as hard as rock crystal, and when dropped on the floor it shivered into a thousand pieces.

"The time is certainly coming," says Mr. Tripler, "when every great packing house, every market, every hospital, every hotel, and many private houses will have plants for making liquid air. The machinery is not expensive, it can be set up in a tenth part of the space occupied by an ammonia ice machine, and its product can be easily handled and placed where it is most needed. Ten years from now hotel guests will call for cool rooms in summer with as much certainty of getting them as they now call for warm rooms in winter.

"And think of what unspeakable value the liquid air

will be in hospitals. In the first place, it is absolutely pure air; in the second place, the proportion of oxygen is very large, so that it is vitalizing air. Why, it will not be necessary for the tired-out man of the future to make his usual summer trip to the mountains. He can have his ozone and his cool heights served to him in his room. Cold is always a disinfectant; some disease germs, like yellow fever, it kills outright. Think of the value of a 'cold ward' in a hospital, where the air could be kept absolutely fresh, and where nurses and friends could visit the patient without fear of infection!"

The property of liquid air to promote rapid combustion will make it invaluable, Mr. Tripler thinks, for use as an explosive. A bit of oily waste, soaked in liquid air, was placed inside of a small iron tube, open at both ends. This was laid inside of a larger and stronger pipe, also open at both ends. When the waste was ignited by a fuse, the explosion was so terrific that it not only blew the smaller tube to pieces, but it burst a great hole in the outer tube. Mr. Tripler thinks that by the proper mixture of liquid air with cotton, wool, glycerine, or any other hydrocarbon, an explosive of enormous power could be produced. And unlike dynamite or nitroglycerine, it could be handled like so much sand, there being not the slightest danger of explosion from concussion, although, of course, it would have to be kept away from fire. It will take many careful experiments to ascertain the best method for making this new explosive, but think of the reward for its successful application! The expense of heavy ammunition and its difficult transportation and storage would be entirely done

away with. No more would warships be loaded down with cumbersome explosives, and no more could there be terrible powder explosions on shipboard, because the ammunition could be made for the guns as it was needed, a plant on shipboard furnishing the necessary liquid air.

Liquid air, owing to the large amount of oxygen which it contains, will make steel burn violently. Mr. Tripler placed a little of it in a tumbler made of ice, and then thrust into it a steel spring having at the end a lighted match. The moment the steel strikes the liquid air it burns like a splinter of fat pine. This experiment shows a most astonishing range of temperature. Here is steel burning at 3500° above zero in an ice receptacle containing liquid air at 312° below zero.

But all other uses of liquid air fade into insignificance when compared with the possibility of its utilization as power for running machinery, which is Mr. Tripler's chief object. I saw Mr. Tripler admit a quart or more of the liquid air into a small engine. A few seconds later the piston began to pump vigorously, driving the fly-wheel as if under a heavy head of steam. The liquid air had not been forced into the engine under pressure, and there was no perceptible heat under the boiler; indeed, the tube which passed for a boiler was soon shaggy with white frost. Yet the little engine stood there in the middle of the room, running apparently without motive power, making no noise and giving out no heat and no smoke, and producing no ashes. And that is something that can be seen nowhere else in the world.

"If I can make little engines run by this power, why not big ones?" asks Mr. Tripler.

"And run them entirely with air?"

"Yes, with liquid air in place of the water now used in steam boilers, and the ordinary heat of the air instead of the coal under the boilers. Air is the cheapest material in the world, but we have only begun learning how to use it. We know a little about compressed and liquid air, but almost nothing about utilizing the heat of the air. Coal is only the sun's energy stored up. What I do is to use the sun's energy direct.

"It is really one of the simplest things in the world," Mr. Tripler continued, "when you understand it. In the case of a steam engine you have water and coal. You must take heat enough out of the coal, and put it into the water to change the water into a gas — that is, steam. The expansion of this gas produces power, and the water will not give off any steam until it has reached the boiling point of 212° Fahrenheit.

"Now steam bears the same relation to water that air does to liquid air. Air is a liquid at 312° below zero — a degree of cold that we can hardly imagine. If you raise it above 312° below zero it boils, just as water boils above 212°. Now, then, we live at a temperature averaging, say, 70° above zero — about the present temperature of this room. In other words, we are 382° warmer than liquid air. Therefore, compared with the cold of liquid air we are living in a furnace. A race of people who could live at 312° below zero would shrivel up as quickly in this room as we should if we were shut up in a baking oven. Now, then, you have liquid air — a liquid at 312° below zero. You expose it to the heat of this furnace in which we live, and it boils instantly and throws off a

vapor which expands it and produces power. That 's simple, is n't it?"

It did seem simple; and you remember with admiration that Mr. Tripler is the first man who ever ran an engine with liquid air, as he was also the first to invent a machine for making liquid air in quantities.

In some respects liquid air possesses a vast supremacy over steam. In the first place, it has about one hundred times the expansive power of steam. In the second place, it begins to produce power the instant it is exposed to the atmosphere. In making steam, water has first to be raised to a temperature of 212° Fahrenheit. That is, if the water as it enters the boiler has a temperature of 50°, 162° of heat must be put into it before it will yield a single pound of pressure. After that, every additional degree of heat produces one pound of pressure, whereas every degree of heat applied to liquid air gives about twenty pounds of pressure.

"Liquid air can be applied to any engine," says Mr. Tripler, "and used as easily and as safely as steam. You need no large boiler, no water, no coal, and you have no waste. The heat of the atmosphere, as I have said before, does all the work of expansion."

The advantages of compactness, and the ease with which liquid air can be made to produce power by the heat of the atmosphere, at once suggested its use in all kinds of motor vehicles. A satisfactory application may do away with the present huge, misshapen, machinery-laden automobiles, and make possible small, light, and inexpensive motors.

Much has yet to be done before liquid air becomes the

revolutionizing power of which Mr. Tripler has prophesied. It has many disadvantages as well as advantages, and it will undoubtedly take Mr. Tripler and other inventors many years to perfect the machines necessary for using it practically. It will probably be chiefly valuable in cases where a source of power must be produced at one place and used at another. This much, however, has been positively accomplished: A machine has been built which will make liquid air in large quantities at small expense, and an engine has been successfully run by liquid air. Other developments will undoubtedly come later.

A CRATER FULL OF SULPHUR

(Abridged)

By John M. Oskison

IN 1903, the United States imported 188,888 tons of sulphur; none was exported. In 1907, the imports had fallen to 20,399 tons, and 35,000 tons were exported. This reversal resulted from the perfection of Mr. Frasch's remarkable plan for raising sulphur in liquid form from the deposits in Calcasieu Parish, Louisiana, and marketing it.

A thousand feet below the surface, apparently filling the cone of a great geyser that had been active in the Tertiary period, lies this bed of sulphur, more than 99½ per cent pure, mixed with limestone in the proportion of 70 per cent sulphur and 30 per cent limestone. The bed is nearly circular in shape, more than half a mile in diameter and known to be eleven hundred feet thick in places. Directly above it is a stratum of quicksand five hundred feet thick; and, until Mr. Frasch undertook the job, this quicksand defeated every attempt made to get at the sulphur. An Austrian company, a French company, and several American companies had tried without success to sink a shaft to the sulphur deposit and to mine it in the usual way.

Mr. Frasch first heard of the Calcasieu Parish deposit and the problem of its exploitation in 1891. He secured a core of the sulphur from one of the wells which

had been sunk, gathered all the available data, and set to work on the problem.

"I decided," he said, "that the only way to mine this sulphur was to melt it in the ground and pump it to the surface in liquid form. . . . I realized from the outset that a method entirely different from that employed in the mines of Sicily was necessary for success here, as the class of labor required to operate this mine would demand at least five dollars a day, whereas the Sicilian miners were being paid sixty cents a day." There spoke the industrial researcher who had been trained not only to think scientifically but along extremely practical lines, too.

Well-drilling equipment was crude then, and nearly nine months were required to sink a ten-inch pipe through two hundred feet of the sulphur deposit. (It can be done in three days now.) Inside the ten-inch pipe Mr. Frasch placed another, six inches in diameter, with a strainer at the bottom and a seat to receive a third pipe three inches in diameter. He had the space between the ten-inch pipe and the six-inch pipe packed with sand to brace it against the pressure he foresaw would be produced by the shifting sands and the subsiding rock when the sulphur was removed. It was his plan to force superheated water down between the six-inch pipe and the three-inch pipe, and when the sulphur was melted to pump it up through the three-inch pipe.

Before any possible test could be made, Mr. Frasch had to set up a battery of boilers and superheating cylinders of his own devising sufficient to supply a tremendous quantity of hot water — he had decided that

the water must be heated to 335° Fahrenheit in order to melt the sulphur rock. So twenty 150-horse-power boilers were installed.

"When everything was ready to make the first trial," Mr. Frasch said, in recalling that day in which either complete failure or conspicuous success would be his portion, "we raised steam in the boilers and sent the superheated water into the ground without a hitch." Can you figure what a hitch at that moment would have meant? Mr. Frasch explained: "If for one instant the temperature required should drop below the melting point of sulphur, it would mean failure." It is no wonder that he and his helpers watched anxiously beside the pumps that were forcing the hot water down. Hour after hour they watched, and the steady stream went down without interruption.

After twenty-four hours of steady forcing, Mr. Frasch gave the word to start the engine attached to the "sulphur line." A strain was noted; it increased; the engine was doing work. "More and more slowly," he recalled, "went the engine, more steam was supplied, and at last the man at the throttle sang out at the top of his voice, 'She's pumping!' On the polished rod of the pump appeared a liquid, and when I wiped it off with my finger I found my finger covered with sulphur.

"Within five minutes, the receptacles under pressure were opened, and a beautiful stream of the golden fluid shot into the barrels we had ready. After pumping for about fifteen minutes, the forty barrels we had supplied were seen to be inadequate. Quickly we threw up embankments and lined them with boards ready to re-

ceive the sulphur that was gushing forth; and since that day no further attempt has been made to provide a vessel or mould.

"When the sun went down we stopped pumping until we could prepare to receive more of the liquid in the morning. The material on the ground had to be removed, and willing hands helped to make a clean slate for the next day."

After working far into the night to clear away the piled-up sulphur, which began to harden almost immediately upon falling from the pump, Mr. Frasch's helpers went home and left him alone. Alone, he took that first heady taste of success which can never be tasted a second time.

"I mounted the sulphur pile," confessed Mr. Frasch, "and seated myself on the very top. It pleased me to hear the slight noise caused by the contraction of the warm sulphur. It was like a greeting from below — proof that my object had been accomplished."

Of course, Mr. Frasch's project had become known long before, but it had drawn out only skeptical comments. Sitting there in the night on his pile of cooling sulphur, he realized the experimenter's supreme joy, that of achieving a dream.

Once pumping was well under way, there arose the puzzle of how to save the pipes from being crushed and wrenched as the sulphur and lime rock subsided to fill up the cavities that were left by the melted and raised sulphur; to prevent this, a twelve-inch pipe with telescope joints was sunk outside the ten-inch pipe and the space between was stuffed. It became necessary to re-

place with earth the thousands of tons of material that were pumped up, and a dredging plant with a capacity of four thousand tons a day was installed.

At one time a well ceased producing while the pipes were still intact. Mr. Frasch was called to find an explanation; he worked out the theory that "wild waters" entering the melting zone had proved to be so extensive that they lowered the temperature of the superheated water below the melting-point. So Mr. Frasch proceeded to "seal" the melting zone away from the harmful flow by pumping sawdust down until it filled the crevices. In five days he forced thirty carloads of sawdust down, and after that was done the well produced 39,000 tons more before the subsiding rock crushed it.

Year by year, the plant in Louisiana became a thing of huge dimensions. To supply the superheated water for the eight wells Mr. Frasch had sunk, he erected eight batteries of boilers, their work being to heat to 335° Fahrenheit 7,000,000 gallons of water a day. The huge cylinders in which this daily ocean of water is superheated were devised by Mr. Frasch. So adequately did he meet and solve the practical requirements of the plant that now the only limitation on production is the demand of the market.

From the first day of pumping, the liquid sulphur has been poured into the center of bins; from that point it flows slowly to the sides and hardens. These bins have become literal mountains of sulphur. As the sulphur flows, spreads, and rises, the boards are raised, sometimes as high as sixty-five feet; and when the stream is diverted to a fresh bin there remains a block of hard

sulphur one hundred and fifty feet wide, two hundred and fifty feet long, and sixty-five feet high. Railroad tracks are laid alongside, the boards are taken off, the sulphur block is broken up by blasting, and grab buckets, operated by a steam crane, load a thirty-five ton car in fourteen minutes. For export, the loaded cars are run upon the company's dock at Sabine, where a seventy-five hundred ton steamship may be loaded in twelve hours.

DYNAMITE

By Joseph Husband

ISOLATED and avoided, the high explosive plant lies half hidden in a waste of sloughs and sand dunes. Like the barren country that surrounds it, the plant itself seems a part of desolate nature, stunted and storm-beaten as the wind-swept hills. Against the straight line of the horizon rise no massive structures of steel or stone; no sound of man or machine breaks the soft stillness; no smoke clouds stain the blue of the autumn sky. Half buried in the rolling sand a hundred small green buildings scatter in wild disorder along winding paths among the scrub oaks. The voices of undisturbed wild fowl rise from the fens and marsh land.

In the little office at the gate I left my matches and put on a pair of soft wooden-pegged powder shoes. Outside, the faint flavor of last night's frost freshened the morning air, and above the red and yellow of the scrub oaks the autumn sun was shining in a pale-blue sky.

At my side the superintendent was explaining the processes of manufacture I was soon to see, but my mind was curiously unresponsive; in the peace of the morning air an ominous presence seemed to surround me; an invisible force that needed but a spark or the slightest impulse to awaken it, annihilating and devastating in its sudden fury.

Beyond the office, like the letter "S" a high sand dune bent in a general east and west direction, a sweep of marsh land in each sheltering curve. Against the outer bank of its first wide crescent the small power plant and a row of red one-story buildings marked a single street. From the open door of the power house the rhythmic drone of a generator accentuated the stillness. Down a track between the buildings a horse plodded slowly over the worn ties, dragging a small flatcar, the driver leaning lazily against one of the uprights which supported a dingy awning.

The manufacture of dynamite consists of two separate processes, which are conducted individually up to a certain point, when their products meet and by their union the actual dynamite is produced. In the little buildings by the power house the first of these products was in course of manufacture. Here the fine wood dust, mixed with other materials, was prepared, an absorbent to hold the nitroglycerine which was being made a half-mile beyond the nearest sand dune. Packed in paper cartridges the nitroglycerine-soaked "dope," or sawdust, is called by a single name — Dynamite.

In two great open pans slowly revolving paddles were turning over and over a mass of wood pulp, fine and soft as snow. The room was warm from the sunshine on the low roof and the drying fires below the pans; there was a strong, clean smell of sawdust. The building was deserted; unattended the paddles swung noiselessly with the low sound of well-oiled machinery.

Inside the next building a couple of men were weighing great measures of white powder from bins along the

wall. The superintendent picked up a printed slip from a desk by the window.

"Nitrate of soda, nitrate of ammonia, wood pulp, marble dust. That's the formula for this batch. Sometimes we put in sulphur, or flour, or magnesium carbonate. It's all according to what kind of explosive is wanted; what it's to be used for."

Far down at the end of the little street the strong, hot smell of paraffine hung heavy in the air. Inside, against the walls of the buildings, the paper cartridges were drying; racks of waxed yellow tubes half filled the building.

Here the first process of manufacture was completed. Stable and harmless, the fragrant wood dust was being prepared for its union with that strange evanescent spirit which would endow it with powers of lightning strength and rapidity.

With our powder shoes sinking in the sliding sand we climbed the path to the top of the hill which marked the center of the twisted dune. In its summit the frame building of the nitrater notched the sky. Here, in the silence between earth and clouds, a mighty force was seeking birth.

Perched on a high stool, an old man in overalls bent intently over the top of a great tank, his eyes fixed on a thermometer that protruded from its cover. Above, a shaft and slowly turning wheels moved quietly in the shadows of the roof. There was a splashing of churning liquid, and the bite of acid sharpened the air. The old man turned his head for a moment to nod to us. Below his feet a coil of pipes white with a thick frost rime en-

tered the bottom of the tank, a cooling solution to keep the temperature of the churning acid within the limit of safety.

As we stepped inside the doorway, the splashing grew louder; the bitter reek of the acid seemed to scorch my nostrils. Slowly the old man turned a valve beside him and a thick trickle of glycerine flowed heavily into an opening in the top of the tank. Inside the blackened caldron a strange transformation was in progress. Were the glycerine allowed to become completely nitrated by the acid the windows of the distant city would rattle in the blast that would surely follow. Carefully, the nitrating must be brought almost to that danger-point and abruptly arrested; so near, that later in the form of dynamite the nitrating could be instantly completed and the desired explosion obtained by the jarring impulse of an electric spark. Like a child pushing a dish to poise on the table edge the old man was bringing this dynamic mixture to a precarious balance.

The superintendent pointed to a cistern filled with water behind the nitrater.

"Before we had the brine pipes to keep the acid cool, it used to heat up occasionally. It gives up red fumes when it passes the danger-point. You ought to see the quick work Old Charley used to do, — open that faucet in the nitrater to let the acid and glycerine dump into the cistern and drown; blow the alarm whistle, and then everybody beat it!"

The old man looked up from the thermometer. "She's ready."

Deliberately he climbed down from the stool and

opened a switch behind him; the splashing of the paddles ceased; the process was completed.

Behind the tank an earthenware faucet opened into a long lead gutter that passed out of the building. Fascinated, I watched him as he slowly turned the handle. From the spout a stream of viscous liquid gushed noisily and flowed off in a sullen current.

"Nitroglycerine," — the superintendent pointed his finger at the splashing stream; "of course, it's impure now, mixed with acid. We'll see it purified in the separating-houses."

I was disappointed. Vaguely I had expected something would happen; how could this dull, oily liquid be that fearful thing that had been represented.

"There's enough in that trough now to wreck a battleship," he added.

Under the crest of a curving hill a half-mile away, was the mix house. From the nitrater we had followed the nitroglycerine through the dangerous process of its separation from the acid, its perfect neutralization. Here, at last, the explosive fluid would assume its final form. Mixed with the absorbent dope, in a crumby consistency it would become dynamite.

The sunshine filled the little room with yellow light; a blue fly buzzed noisily against the window. Facing the flat marsh land the building rested in a deep cut in the hillside; behind it the solid hill, on either side an artificial embankment or barricade of sand and timber. In the center of the room was a cumbersome machine like an archaic mill for crushing grain. Hung from an axle revolving on a perpendicular central shaft, two great

wooden wheels, four feet in diameter, rested in a circular trough; a pair of giant cart wheels with broad, smooth tires of pine.

There was a sound outside the building. Down a board walk that disappeared behind a hill in the direction of the separating-house, came a man pushing a square wagon completely covered with rubber blankets, — three hundred pounds of nitroglycerine.

Swiftly the two workmen filled the circular trough with the prepared wood pulp. The wagon was trundled softly into the room. From a tank in the corner a measure of brown, sweet-smelling, aromatic oil was mixed into the contents of the cart.

Something was going to happen. A sudden impulse to run before it was too late seized me. The cart was pushed beside the trough. From a hose in its base a heavy brown fluid gushed over the powdery dope. Slowly the steady stream became a trickle and ceased.

There was a faint sound and I knew that the current was thrown in; the great axle began to revolve on the shaft. One and then the other, the giant wheels turned heavily. Under the advancing ploughs the brown stain of nitroglycerine faded in the yellow of the dope. Round and round; heavily the smooth wheels pressed the flocculent mass, cleanly the sharp ploughs turned furrows behind them — Dynamite.

I started violently at the voice of the superintendent. It seemed hours instead of minutes since this death-taunting machine had begun; hours in which each second might bring annihilation.

"It's mixed."

The wheels ceased to revolve. With wooden shovels the workmen scooped the dynamite from the trough and pitched it into fiber cans, as big as barrels.

As though built to withstand the siege guns of an enemy, the dugouts of the packers faced the marsh in a long straggling line against the hillside. Like the mix house, each building sank deep into the sandbank, its sides protected by enveloping barricades.

In each small cell two men were working. There was little talking. Silence hung heavy over the hills and marsh land; a strange blending of peace and terror that made harsh sounds improper and jarring to the senses.

With quick dexterity the empty paper tubes, that I had seen manufactured when I first began this perilous journey, were inserted in the packing-machine. An abrupt movement, and they were packed with dynamite and laid in boxes beside the workers.

I picked up one of the "sticks" from a half-filled box. "Stump Dynamite."

Hour after hour, day after day, the filled boxes were trundled down the board walk to the magazine. "Stump Dynamite." I had always thought of this great industry as a destructive agency, of high explosives as carriers of death and desolation. But where the forests have vanished before the axes of the woodmen, dynamite is clearing fields for the next year's planting. In the black entries of the mine the undercut coal-face falls shattered at the blast of the explosives. Through the walls of mountain ranges it is tearing loose the solid rock, that trains may some day follow the level rails; through blasted tunnels flows water to moisten the lips of a parch-

ing city; from ocean to ocean it has opened a giant cut that deep-sea vessels may carry their cargoes by shorter routes; deep under the strata of the earth's crust its sudden shock shakes the oil-well into life; its rending breath tears the red ore of iron from the living rock.

Labors of Hercules! What are the feats of the earth-born son of Jupiter to the mighty wonders accomplished by this tabloid thunderbolt. Death and destruction may come from its sharp detonation, but for every life that goes out in siege or battle a hundred lives are sustained by its quiet labor in field or mine.

The afternoon sun was setting behind a mist of autumn clouds. In the silence of the dunes and marsh the clear call of a bird sounded sharp and silver-tuned in a run of hurried melody.

THE MAGNET AS A USEFUL WIZARD

By George Ethelbert Walsh

THE principles of the electric magnet have been known since the earliest days of electric science, and various attempts were made to take advantage of this knowledge for industrial purposes; but it has only been in comparatively recent years that the electromagnet has entered upon its career as one of the most useful devices for handling raw and finished material in iron and steel mills, foundries, and railroad machine shops, and a dozen and one different kinds of manufacturing plants.

Most of us are familiar with the antics performed by iron filings, needles, or small particles of metal when a magnet is pushed within their fields; and the construction of small toys that can be moved about by a small horseshoe magnet has excited our interest, if not our wonder, by their ready response to the invisible power exerted by this little magician. A magician it surely is, judged purely from an optical point of view!

A visit to any of our large steel mills or foundries equipped with electromagnets would still further impress us with the wizardry of this wonderful device, for there we should see invisible fingers picking up mammoth girders, lifting hot steel plates from the fire, separating pieces of iron from scrap of other metals, pulling and

hauling with tremendous power, and always releasing them by a touch of the operator's hand. Their operation is as noiseless as it is swift and sure. There is no clanking and tightening of chains and grappling hooks, no slip of the heavy load as it adjusts itself to the pull, no creaking and groaning of the tackle — nothing but swift, sure, and silent lifting and hauling of the weight to its new position.

If we look more carefully, we shall see the electrical magician work further wonders. If it is in a foundry where scrap iron, steel, copper, brass, and other metals are piled together in a great heap, it will separate the iron and steel from the other metals with a skill surpassing anything else of man's creation. It will sort out and separate these metals from all the others, pulling and hauling at iron and steel pieces lying underneath the brass and copper, and discarding all else with absolute certainty. The foundry, which receives its mixed scrap from all conceivable sources, some of it painted, corroded, and oxidized so that it is difficult to distinguish the different metals without scraping and examining closely, is equipped with a magnetic separator that will do the sorting in a hundredth part of the time required by hand labor.

Although very particular as to what kind of material it will handle, the electric magnet is not at all particular as to how it will manipulate the load. Anything and everything which respond to magnetic attraction that come within its field are picked up. If passed across a scrap-heap, it will gather in its fingers a queer assortment of iron bars, steel shavings, nails, broken pins, and

steel rods. It is a queer collection it hauls up — a mass of material that to handle singly would require an immense amount of work. Its load is limited only by its lifting power, and that is something enormous in these days, approximating five to twelve tons.

If we take a peep into the rolling-mill, we shall witness other peculiar feats of the lifting-magnet. An enormous hot steel plate or girder must be lifted from its bed to some other part of the mill. To touch this, or even to approach within a foot or two of it, would prove dangerous to the workmen. Formerly, when these hot plates had to be lifted without magnets, the workmen were often severely injured in adjusting the chains. To-day, the electric magnet swoops down and picks up the hot plate, and can transport it to any part of the mill. Its fingers are invulnerable to the scorching heat, and it is in no way concerned whether it is a hot or cold load it is called upon to handle. The magnets with their loads are raised, lowered, and moved about by cables operating from what are known as cranes.

In another part of the rolling-mill, we may see a steel plate forty or more feet long, eight feet in width, and only one half an inch in thickness. Now to lift and carry that to another part of the mill used to be a pretty difficult matter. When lifted, it would bend and buckle under its own weight, and, in order to avoid this, the most careful adjustment of many chains was necessary. But several magnets, used in combination on a single crane, pick up the long, thin sheet of metal, and calmly haul it away to the desired spot. With the exception of a little sagging of the plate between the magnets, you would

hardly know that it was being deprived of the support of the ground as it swings silently through the air.

A still further perfection of the industrial magnet may be seen in the handling of the "skull-cracker" by the lifting-magnet. A skull-cracker is simply a huge round or pear-shaped ball of iron suspended by a chain and hook. When dropped on big pieces of metal, it breaks and cracks them into small particles for melting purposes. The combination of skull-cracker and magnet works ideally.

Swiftly and surely the huge ball of iron, weighing from twelve thousand to twenty thousand pounds, rises into the air over a scrap-pile and is allowed to fall upon it, smashing the material into convenient sizes. When the contents of the pile have been sufficiently broken up, the pieces are lifted and carried away by the same magnet. Thus a single operator can smash the plates and then pick up the pieces and drop them into the melting-furnace. It is all done so neatly and easily, that it appears more like magic than actuality.

Other uses of the electromagnet may be seen by visiting a mine where low-grade ores are crushed to obtain the precious metal found in them. When the rocks are crushed and pulverized by the machinery, the magnets are used for picking up the small particles of iron from the ores. By this method of ore-separation, old tailings, that were formerly discarded as worthless, have been made of great value. The iron ore recovered is of sufficient value to build up great industries. Before the big commercial magnets were utilized, all of this low-grade ore was practically wasted.

Next take a peep at a flour mill or a factory where rice chaff is ground into small particles to make cattle food. Enormous attrition machines are used for grinding the chaff, and they consist of two metal disks revolving in opposite directions. These disks are separated by one eighth to three sixteenths of an inch. The disks are indented to give a grinding surface, and they make from fifteen hundred to two thousand revolutions per minute. Now, if a small particle of iron or steel should be caught between these revolving disks, a hot spark would be generated. Many times hot sparks produced in this way have caused disastrous fires by igniting the light, combustible chaff.

In flour mills disastrous explosions have been due to the same cause. The fine dust which collects in flour mills will sometimes explode almost as violently as gunpowder, if a spark is applied to it when suspended in the air.

The use of electric magnets has eliminated the danger of both fire and explosions in these industries. Strong magnets are placed in the attrition machines so that all the chaff must pass in close proximity to them before it reaches the grinding-disks. These magnets are powerful enough to draw out any bits of iron that may be mixed in the chaff. Similar contrivances are used in flour mills, and they have reduced the danger of explosions and fires from this cause almost to a minimum. Sometimes a collection of nearly a pound of small pieces of iron is removed from the magnets after a run of a few hours of the machinery.

The ever-increasing field of usefulness that the electro-

magnet is operating in to-day furnishes abundant instances of the remarkable value of the device. For instance, a load which had required two men four hours to place in a wagon, was lifted from the same wagon and placed in the storage pile by a magnet in just two and one half minutes. As a rule, one electric lifting-magnet does the work of a gang of from six to twelve workmen, and the mode of operation is so simple that only one man is needed to manipulate two or three magnets. By means of a simple device, the operator can regulate the current and power of the magnet so that he can pick up one, or two, or any number of pieces at once. If a small beam lies alongside of a larger one, and it is desired to move only the former, the current is proportioned to the lesser weight, and the magnet lifts it without disturbing the heavier one. Thus, in the hands of a skilled operator, the magnet performs the work of sorting and lifting different weights with almost uncanny intelligence. It rejects this piece from a heap, throws another out of the way, and finally picks up the one it has been searching for. In foundries, steel mills, shipbuilding yards, and railroad machine shops, the big electric magnets are continually working, performing jobs of a difficult nature that were formerly done by hand, or by tackle and chain.

When the lifting-magnets were first introduced in our big mills, it was urged against them that there was always the danger of a failing current and the sudden release of the load, when, it was feared, serious injuries would result to the workmen by the fall. But experience has shown that this danger is not to be greatly

feared. Indeed, no more accidents or delays have been caused by a failing current than had been due to the slipping of chains and hooks. In handling enormous weights of this character, there is always present the element of danger, and only care and precaution can eliminate it entirely. The rule in most shops and mills is that no workmen shall pass or stand under the heavy loads carried by cranes and magnets.

Electromagnets in general use in mills and shops differ a good deal in design. The oldest and most popular form was the simple horseshoe. This type has proved inadequate for plate-handling and for many other grades of work. In the efforts to secure the most efficient design, the round magnet was developed, which, for handling certain kinds of compact loads, is unsurpassed. But experience showed that, while a round magnet in a straight pull could easily lift five tons, it was incapable of picking up a long, thin plate weighing only half a ton. As a result of this experience, the engineers designed a special plate-handling magnet.

The design and construction of the magnet for lifting heavy weights must be exact and accurate. Such magnets are proof against heat or cold, and there is practically no danger of short-circuiting. The winding of the coils is the most expensive part of the construction of the giant magnets. In the round type of magnet, there may be as high as three thousand turns of wire, weighing approximately two hundred and twenty pounds.

Small magnets are employed by manufacturing concerns with as great success as the larger ones are used in the mills and shops. For instance, in needle factories

small magnets are used at the end of the working-day for cleaning up the floors and benches. The magnets are passed swiftly along to gather up all the small particles of steel, broken needles, and iron. All this scrap is of value, and its complete separation from the dust and dirt of the shops greatly simplifies operations. The same is true in saw factories and in shops of a general character where a great amount of metal is being cut and filed. The accumulation of fine particles of metal is considerable. Formerly, this was all wasted by sweeping it out with a broom, but to-day the magnet gathers up everything from the finest filings and steel shavings to pieces as large as the fist.

The efficiency of our manufacturing shops and factories is thus greatly promoted by the industrial use of electromagnets, and their application and adaptation to new industries increase every year. Small magnets are also employed in extracting particles of steel and iron from the eyes, lungs, and body, and some notable instances of saving life are set down to its credit.

The magnet is thus a wonderful magician, capable of lifting loads weighing many tons, or gathering particles of metal too small for the fingers to pick up or even for the eye to detect. It will swing gigantic steel plates and girders through the air as easily as a child handles a toy, or draw from the eye infinitesimal specks of iron dust. It has wonderful fingers, invisible but remarkably efficient, that can separate and sort ores and metal scrap in the shop or foundry, or, when needed, extract as a gentle surgeon the broken points of a dagger or needle from the body.

THE ELECTRICAL FURNACE

(Abridged)

By Ray Stannard Baker

WE think of all the substances around us as solids, liquids, and gases, but these are only comparative terms. A change of temperature changes the solid into the liquid, or the gas into the solid. Take water, for instance. In the ordinary temperature of summer it is a liquid, in winter it is a hard crystalline substance called ice; apply the heat of a stove and it becomes steam, a gas. So with all other substances. Air to us is an invisible gas, but if the earth should suddenly drop in temperature to 312° below zero all the air would fall in liquid drops like rain and fill the valleys of the earth with lakes and oceans. Still a little colder and these lakes and oceans would freeze into solids. Similarly, steel seems to us a very hard and solid substance, but apply enough heat and it boils like water, and finally, if the heat be increased, it becomes a gas.

Imagine, if you can, a condition in which all substances are solids; where the vibrations known as heat have been stilled to silence, where nothing lives or moves; where, indeed, there is an awful nothingness and you can form an idea of the region of the coldest cold — in other words, the region where heat does not exist. Our frozen moon gives something of an idea of this condition, though probably, cold and barren as it is, the moon is

still a good many degrees in temperature above the absolute zero.

Our interest here centers in the other extreme of temperature, where the heat vibrations are inconceivably rapid; where nearly all substances known to man become liquids and gases; where, in short, if the experimenter could go high enough, he could reach the awful degree of heat of the burning sun itself, estimated at over 10,000°. It is the work of exploring these regions of great heat that such men as Moissan, Siemens, Faure, and others have made such remarkable discoveries, reaching temperatures as high as 7000°, or over twice the heat of boiling steel. Their accomplishments seem the more wonderful when we consider that a temperature of this degree burns up or vaporizes every known substance. How, then, could these men have made a furnace in which to produce this heat? Iron in such a heat would burn like paper, and so would brick and mortar. It seems inconceivable that even science should be able to produce a degree of heat capable of consuming the tools and everything else with which it is produced.

The heat vibrations at 7000° are so intense that nickel and platinum, the most refractory, the most unmeltable of metals, burn like so much beeswax; the best fire-brick used in lining furnaces is consumed by it like lumps of rosin, leaving no trace behind. It works, in short, the most marvelous, the most incredible transformations in the substances of the earth.

Indeed, we have to remember that the earth itself was created in a condition of great heat — first a swirling, burning gas, something like the sun of to-day, gradu-

ally cooling, contracting, rounding, until we have our beautiful world, with its perfect balance of gases, liquids, solids, its splendid life. A dying volcano here and there gives faint evidence of the heat which once prevailed over all the earth.

It was in the time of great heat that the most beautiful and wonderful things in the world were wrought. It was fierce heat that made the diamond, the sapphire, and the ruby; it fashioned all of the most beautiful forms of crystals and spars; and it ran the gold and silver of the earth in veins, and tossed up mountains, and made hollows for the seas. It is, in short, the temperature at which worlds were born.

More wonderful, if possible, than the miracles wrought by such heat is the fact that men can now produce it artificially; and not only produce, but confine and direct it, and make it do their daily service. One asks himself, indeed, if this can really be; and it was under the impulse of some such incredulity that I lately made a visit to Niagara Falls, where the hottest furnaces in the world are operated. Here clay is melted in vast quantities to form aluminum, a metal as precious a few years ago as gold. Here lime and carbon, the most infusible of all the elements, are joined by intense heat in the curious new compound, calcium carbide, a bit of which dropped in water decomposes almost explosively, producing the new illuminating gas, acetylene. Here, also, pure phosphorus and the phosphates are made in large quantities; and here is made carborundum — gem-crystals as hard as the diamond and as beautiful as the ruby.

An extensive plant has also been built to produce the heat necessary to make graphite such as is used in lead pencils, and for lubricants, stove-blacking, and so on. Graphite has been mined from the earth for thousands of years; it is pure carbon, first cousin to the diamond. Ten years ago the possibility of its manufacture would have been scouted as ridiculous; and yet in these wonderful furnaces, which repeat so nearly the processes of creation, graphite is as easily made as soap. The marvel-workers at Niagara Falls have not yet been able to make diamonds — in quantities. The distinguished French chemist Moissan has produced them in his laboratory furnaces — small ones, it is true, but diamonds; and one day they may be shipped in peck boxes from the great furnaces at Niagara Falls. This is no mere dream; the commercial manufacture of diamonds has already had the serious consideration of level-headed, far-seeing business men, and it may be accounted a distinct probability. What revolution the achievement of it would work in the diamond trade as now constituted and conducted no one can say.

These marvelous new things in science and invention have been made possible by the chaining of Niagara to the wheels of industry. The power of the falling water is transformed into electricity. Electricity and heat are both vibratory movements of the ether; science has found that the vibrations known as electricity can be changed into the vibrations known as heat. Accordingly, a thousand horse-power from the mighty river is conveyed as electricity over a copper wire, changed into heat and light between the tips of carbon electrodes, and

there works its wonders. In principle the electric furnace is identical with the electric light. It is scarce twenty years since the first electrical furnaces of real practical utility were constructed; but if the electrical furnaces to-day in operation at Niagara Falls alone were combined into one, they would, as one scientist speculates, make a glow so bright that it could be seen distinctly from the moon — a hint for the astronomers who are seeking methods for communicating with the inhabitants of Mars. One furnace has been built in which an amount of heat energy equivalent to 700-horse-power is produced in an arc cavity not larger than an ordinary water tumbler.

On reaching Niagara Falls, I called on Mr. E. G. Acheson, whose name stands with that of Moissan as a pioneer in the investigation of high temperatures.

"I think the possibility of manufacturing genuine diamonds," he said to me, "has dazzled more than one young experimenter. My first efforts in this direction were made in 1880. It was before we had command of the tremendous electric energy now furnished by the modern dynamo, and when the highest heat attainable for practical purposes was obtained by the oxyhydrogen flame. Even this was at the service of only a few experimenters, and certainly not at mine. My first experiments were made on what I might term the 'wet way'; that is, by the process of chemical decomposition by means of an electric current. Very interesting results were obtained, which even now give promise of value; but the diamond did not materialize.

"I did not take up the subject again until the dynamo

had attained high perfection and I was able to procure currents of great power. Calling in the aid of the 6500° Fahrenheit or more of temperature produced by these electric currents, I once more set myself to the solution of the problem. I now had, however, two distinct objects in view: first, the making of a diamond; and, second, the production of a hard substance for abrasive purposes. My experiments in 1880 had resulted in producing a substance of extreme hardness, hard enough, indeed, to scratch the sapphire — the next hardest thing to the diamond — and I saw that such a material, cheaply made, would have great value.

"My first experiment in this new series was of a kind that would have been denounced as absurd by any of the old-school book-chemists, and had I had a similar training, the probability is that I should not have made such an investigation. But 'fools rush in where angels fear to tread,' and the experiment was made."

This experiment by Mr. Acheson, extremely simple in execution, was the first act in rolling the stone from the entrance to a veritable Aladdin's cave, into which a multitude of experimenters have passed in their search for Nature's secrets; for, while the use of the electric furnace in the reduction of metals — in the breaking down of Nature's compounds — was not new, its use for synthetic chemistry — for the putting together, the building up, the formation of compounds — was entirely new. It has enabled the chemist not only to reproduce the compounds of Nature, but to go further and produce valuable compounds that are wholly new and were heretofore unknown to man. Mr. Acheson

conjectured that carbon, if made to combine with clay, would produce an extremely hard substance; and that, having been combined with the clay, if it should in the cooling separate again from the clay, it would issue out of the operation as diamond. He therefore mixed a little clay and coke dust together, placed them in a crucible, inserted the ends of two electric light carbons into the mixture, and connected the carbons with a dynamo. The fierce heat generated at the points of the carbons fused the clay, and caused portions of the carbon to dissolve. After cooling, a careful examination was made of the mass, and a few small purple crystals were found. They sparkled with something of the brightness of diamonds, and were so hard that they scratched glass. Mr. Acheson decided at once that they could not be diamonds; but he thought they might be rubies or sapphires. A little later, though, when he had made similar crystals of a larger size, he found that they were harder than rubies, even scratching the diamond itself. He showed them to a number of expert jewelers, chemists, and geologists. They had so much the appearance of natural gems that many experts to whom they were submitted without explanation decided that they must be certainly of natural production. Even so eminent an authority as Geikie, the Scotch naturalist, on being told, after he had examined them, that the crystals were manufactured in America, responded testily: "These Americans! What won't they claim next? Why, man, those crystals have been in the earth a million years."

Mr. Acheson decided at first that his crystals were a combination of carbon and aluminium, and gave them

the name "carborundum." He at once set to work to manufacture them in large quantities for use in making abrasive wheels, whetstones, and sandpaper, and for other purposes for which emery and corundum were formerly used. He soon found by chemical analysis, however, that carborundum was not composed of carbon and aluminium, but of carbon and silica, or sand, and that he had, in fact, created a new substance; so far as human knowledge now extends, no such combination occurs anywhere in nature. And it was made possible only by the electrical furnace, with its power of producing heat of untold intensity.

In order to get a clear understanding of the actual workings of the electrical furnace, I visited the plant where Mr. Acheson makes carborundum. The furnace room is a great, dingy brick building, open at the sides like a shed. It is located only a few hundred yards from the banks of the Niagara River and well within the sound of the great falls. Just below it, and nearer the city, stands the handsome building of the Power Company, in which the mightiest dynamos in the world whir ceaselessly day and night, while the waters of Niagara churn in the water-wheel pits below. Heavy copper wires carrying a current of 2200 volts lead from the power house to Mr. Acheson's furnaces, where the electrical energy is transformed into heat.

There are ten furnaces in all, built loosely of firebrick, and fitted at each end with electrical connections. And strange they look to one who is familiar with the ordinary fuel furnace, for they have no chimneys, no doors, no drafts, no ash-pits, no blinding glow of heat

and light. The room in which they stand is comfortably cool. Each time a furnace is charged, it is built up anew; for the heat produced is so fierce that it frequently melts the bricks together, and new ones must be supplied. There were furnaces in many stages of development. One had been in full blast for nearly thirty hours, and a weird sight it was. The top gave one the instant impression of the seamy side of a volcano. The heaped coke was cracked in every direction, and from out of the crevices and depressions and from between the joints of the loosely built brick walls gushed flames of pale green and blue, rising upward, and burning now high, now low, but without noise beyond a certain low humming. Within the furnace — which was oblong in shape, about the height of a man, and sixteen feet long by six wide — there was a channel, or core, of white-hot carbon in a nearly vaporized state. It represented graphically in its seething activity what the burning surface of the sun might be — and it was almost as hot. Yet the heat was scarcely manifest a dozen feet from the furnace, and but for the blue flames rising from the cracks in the envelope, or wall, one might have laid his hand almost anywhere on the bricks without danger of burning it.

In the best modern blast furnaces, in which the coal is supplied with special artificial draft to make it burn the more fiercely, the heat may reach 3000° Fahrenheit. This is less than half of that produced in the electrical furnace. In porcelain kilns, the potters, after hours of firing, have been able to produce a cumulative temperature of as much as 3300° Fahrenheit; and this, with the oxyhydrogen flame (in which hydrogen gas is spurred to

greater heat by an excess of oxygen), is the very extreme of heat obtainable by any artificial means except by the electrical furnace.

Mr. Fitzgerald, the chemist of the Acheson Company, pointed out to me a curious glassy cavity in one of the half-dismantled furnaces. "Here the heat was only a fraction of that in the core," he said. But still the fire-brick — and they were the most refractory produced in this country — had been melted down like butter. The floors under the furnace were all made of fire-brick, and yet the brick had run together until they were one solid mass of glassy stone. "We once tried putting a fire-brick in the center of the core," said Mr. Fitzgerald, "just to test the heat. Later, when we came to open the furnace, we could n't find a vestige of it. The fire had totally consumed it, actually driving it all off in vapor."

Indeed, so hot is the core that there is really no accurate means of measuring its temperature, although science has been enabled by various curious devices to form a fairly correct estimate. The furnace has a provoking way of burning up all of the thermometers and heat-measuring devices which are applied to it. A number of years ago a clever German, named Segar, invented a series of little cones composed of various infusible earths like clay and feldspar. He so fashioned them that one in the series would melt at 1620° Fahrenheit, another at 1800°, and so on up. If the cones are placed in a pottery kiln, the potter can tell just what degree of temperature he has reached by the melting of the cones one after another. But in Mr. Acheson's electrical furnaces all the

cones would burn up and disappear in two minutes. The method employed for coming at the heat of the electrical furnace, in some measure, is this: a thin filament of platinum is heated red hot — 1800° Fahrenheit — by a certain current of electricity. A delicate thermometer is set three feet away, and the reading is taken. Then, by a stronger current, the filament is made white-hot — 3400° Fahrenheit — and the thermometer moved away until it reads the same as it read before. Two points in a distance-scale are thus obtained as a basis of calculation. The thermometer is then tried by an electrical furnace. To be kept at the same marking it must be placed much farther away than in either of the other instances. A simple computation of the comparative distances with relation to the two well-ascertained temperatures gives approximately, at least, the temperature of the electrical furnace. Some other methods are also employed. None is regarded as perfectly exact; but they are near enough to have yielded some very interesting and valuable statistics regarding the power of various temperatures. For instance, it has been found that aluminum becomes a limpid liquid at from 4050° to 4320° Fahrenheit, and that lime melts at from 4940° to 5400°, and magnesia at 4680°.

There are two kinds of electrical furnaces, as there are two kinds of electric lights — arc and incandescent. Moissan has used the arc furnace in all of his experiments, but Mr. Acheson's furnaces follow rather the principle of the incandescent lamp. "The incandescent light," said Mr. Fitzgerald, "is produced by the resistance of a platinum wire or a carbon filament to the pas-

sage of a current of electricity. Both light and heat are given off. In our furnace, the heat is produced by the resistance of a solid cylinder or core of pulverized coke to the passage of a strong current of electricity. When the core becomes white-hot, it causes the materials surrounding it to unite chemically, producing the carborundum crystals."

The materials used are of the commonest — pure white sand, coke, sawdust, and salt. The sand and coke are mixed in the proportions of sixty to forty, the sawdust is added to keep the mixture loose and open, and the salt to assist the chemical combination of the ingredients. The furnace is half filled with this mixture, and then the core of coke, twenty-one inches in diameter, is carefully moulded in place. This core is sixteen feet long, reaching the length of the furnace, and connecting at each end with an immense carbon terminal, consisting of no fewer than twenty-five rods of carbon, each four inches square and nearly three feet long. These terminals carry the current into the core from huge insulated copper bars connected from above. When the core is complete, more of the carborundum mixture is shoveled in, and tamped down until the furnace is heaping full.

Everything is now ready for the electric current. The wires from the Niagara Falls power plant come through an adjoining building, where one is confronted, upon entering, with this suggestive sign: —

DANGER

2200 Volts

Tesla produces immensely higher voltages than this for laboratory experiments, but there are few more powerful currents in use in this country for practical purposes. Only about 2000 volts are required for executing criminals under the electric method employed in New York; 400 volts will run a trolley car. It is hardly comfortable to know that a single touch of one of the wires or switches in this room means almost certain death. Mr. Fitzgerald gave me a vivid demonstration of the terrific destructive force of the Niagara Falls current. He showed me how the circuit was broken. For ordinary currents, the breaking of a circuit simply means a twist of the wrist and the opening of a brass switch. Here, however, the current is carried into a huge iron tank full of salt water. The attendant, pulling on a rope, lifts an iron plate from the tank. The moment it leaves the water, there follow a rumbling crash like a thunder-clap, a blinding burst of flame, and thick clouds of steam and spray. The sight and sound of it make you feel delicate about interfering with a 2200-volt current.

This current is, indeed, too strong in voltage for the furnaces, and it is cut down, by means of what were until recently the largest transformers in the world, to about 100 volts, or one fourth the pressure used on the average trolley line. It is now, however, a current of great intensity — 7500 ampères, as compared with the one half ampère used in an incandescent lamp; and it requires eight square inches of copper and 400 square inches of carbon to carry it.

Within the furnace, when the current is turned on, a thousand horse-power of energy is continuously trans-

formed into heat. Think of it! Is it any wonder that the temperature goes up? And this is continued for thirty-six hours steadily, until 36,000 "horse-power hours" are used up and 7000 pounds of the crystals have been formed. Remembering that 36,000 horse-power hours, when converted into heat, will raise 72,000 gallons of water to the boiling point, or will bring 350 tons of iron up to a red heat, one can at least have a sort of idea of the heat evolved in a carborundum furnace.

When the coke core glows white, chemical action begins in the mixture around it. The top of the furnace now slowly settles, and cracks in long, irregular fissures, sending out a pungent gas which, when lighted, burns lambent blue. This gas is carbon monoxide, and during the process nearly six tons of it were thrown off and wasted. It seems, indeed, a somewhat extravagant process, for fifty-six pounds of gas are produced for every forty of carborundum.

"It is very distinctly a geological condition," said Mr. Fitzgerald; "crystals are not only formed exactly as they are in the earth, but we have our own little earthquakes and volcanoes." Not infrequently gas collects, forming a miniature mountain, with a crater at its summit, and blowing a magnificent fountain of flame, lava, and dense white vapor high into the air, and roaring all the while in a most terrifying manner. The workmen call it a "blowing off."

At the end of thirty-six hours the current is cut off, and the furnace is allowed to cool, the workmen pulling down the brick as rapidly as they dare. At the center of

the furnace, surrounding the core, there remains a solid mass of carborundum as large in diameter as a hogshead. Portions of this mass are sometimes found to be composed of pure, beautifully crystalline graphite. This in itself is a surprising and significant product, and it has opened the way directly to graphite-making on a large scale. An important and interesting feature of the new graphite industry is the utilization it has effected of a product from the coke regions of Pennsylvania which was formerly waste.

To return to carborundum: when the furnace has been cooled and the walls torn away, the core of carborundum is broken open, and the beautiful purple and blue crystals are laid bare, still hot. The sand and the coke have united in a compound nearly as hard as the diamond and even more indestructible, being less inflammable and wholly indissoluble in even the strongest acids. After being taken out, the crystals are crushed to powder and combined in various forms convenient for the various uses for which it is designed.

I asked Mr. Acheson if he could make diamonds in his furnaces. "Possibly," he answered, "with certain modifications." Diamonds, as he explained, are formed by great heat and great pressure. The great heat is now easily obtained, but science has not yet learned Nature's secret of great pressure. Moissan's method of making diamonds is to dissolve coke dust in molten iron, using a carbon crucible into which the electrodes are inserted. When the whole mass is fluid, the crucible and its contents are suddenly dashed into cold water or melted lead. This instantaneous cooling of the iron produces

enormous pressure, so that the carbon is crystallized in the form of diamond.

But whatever it may or may not be able to do in the matter of diamond-making, there can be no doubt that the possibilities of the electrical furnace are beyond all present conjecture. With American inventors busy in its further development, and with electricity as cheap as the mighty power of Niagara can make it, there is no telling what new and wonderful products, now perhaps wholly unthought-of by the human race, it may become possible to manufacture, and manufacture cheaply.

A MOVING PICTURE OF THE STORY OF THE EARTH

(*Abridged*)

By Charles R. Gibson

WHEN our picture begins, we think that the cinematograph is not working properly, for we cannot see anything but a sort of hazy cloud. Soon we see what appears to be a great whirling mass of glowing gas. As this whirls round and round in space, we see pieces of it being thrown off, and we notice that while these tend to fly straight away out of the picture, they are evidently pulled round by the attraction of the central glowing mass, and they remain in the picture, going round and round the parent mass.

As the moving picture proceeds, we recognize the central glowing mass as our sun, and the smaller objects are the planets of the solar system. We see that the planets circle around the sun at very different distances, and those nearer to the sun get round their course very much quicker than those at a distance. Of course, they have not nearly so far to go round, but they are also traveling very much faster.

The operator calls our special attention to the planet which is third from the sun. He explains that this is the great ball on which we now live. It is one of the smallest of the eight planets, but as it is the one in which we are specially interested, the operator changes the set-

ting of his picture, so that he may show us the earth on a larger scale; the whole screen is now occupied by the central part, showing the earth revolving around the sun.

Now we see the sun better, and next to it we see a very small planet, which, if measured through the center, is less than half the size of the earth. We are told that this planet is called Mercury.

Next to this planet comes one which looks exactly like the earth, but it is really a little smaller. It has been named Venus. Then comes the earth, but in the picture it is still a glowing red-hot ball.

Just on the very edge of the picture we see another planet, Mars, which we notice is very much smaller than the earth. But the operator leaves the sun out of account now, and places the earth in the center of the screen.

As this red-hot ball whirls round, we see a part of it thrown off into space, just as the sun threw off planets. This piece of the earth behaves just as the planets did. It looks at first as if it were going right away from the earth, but it is gradually pulled round until it circles the earth at a respectful distance. As this piece of the earth cools down, we recognize it as our faithful friend the moon. It has cooled down much quicker than the earth, but we are not surprised at this, as it is very much smaller. The earth is still red-hot when the moon has become cool, but in a later picture we see that the earth has also ceased to glow.

The earth and the moon have both ceased to give out light, but you say that they are shining in the picture.

They are, but they are only reflecting the light from the sun, just as any object on earth does.

One of our party suggests that in the moving picture the earth now looks very like a giant snowball, but that is because it is inclosed in a great cloak of clouds. Although it is no longer red-hot, it is still very hot, for we notice that when some of the clouds condense and fall on to the earth as water, it forms oceans of boiling and steaming water.

In a little while we see things more clearly, for the boiling waters have cooled down, and the cold clouds of water vapor have floated upwards in an invisible ocean of air.

Now we can see that there are large continents of dry land, but we cannot distinguish any of the well-known shapes which we find on our maps. We need not look for them, as they were not there in those early days. We are not surprised that there is more water than dry land, for we have noticed that on the maps of the world today.

We see the great ball turning round and round at a comparatively slow speed, which is arranged so that we may see the different changes that take place. It is interesting to watch the changes in the dry land and the sea. What was one continent of dry land is now broken up into several large patches of land with some islands between.

While we are watching great mountains rising up very slowly on the dry land, a great many other changes are taking place; but the operator wishes us to see more of the detail of the changes that are taking place, so he will

enlarge one part of the great ball and let that part occupy the whole screen. It is just as though we had come very much nearer to the earth, and could see only a small part at a time.

We see great rivers washing down fine sand or sediment to the sea. We watch it gathering along the bed of the ocean, and in time we see it hardening and becoming a great bed of solid rock. The operator tells us that this took thousands and thousands of years to happen.

Now he shows us great beds of chalk being laid down. It looks as if they were being made out of nothing, but the operator tells us that they are being built up of millions and millions of these tiny and almost invisible shells. These float about in the ocean so long as the little creatures in them are alive, and when these small specks of living jelly die, then the shells fall to the bottom of the ocean. After long ages they become one solid mass of chalk and to-day we see them as great chalk cliffs around the shores of England.

Now the picture is of a part of the ocean, in which we see a great many jellyfishes, starfishes, and seaweeds. By and by we notice some curious legless creatures rolling along the bottom of the ocean; then we see some very funny-looking fish in armor plate; but just then the operator turns the picture to a part of the dry land.

Here we see that some of the seaweeds have spread right up on to the land and later on we find that the descendants of these have settled down as land plants. But the operator hurries his film forward till we come to the most luxuriant foliage we have ever seen. Indeed, we might think that we were looking through some great

magnifying glass, the ferns and horse-tail plants look so large. But we can see from the fish swimming about in the muddy water, and from the snails on the ferns, that the plants are really giant ones.

The next time that the operator shows us the same place, we find that the forest of fern trees is disappearing below the water. Later on we see the same place again, and we remark that the plants do not seem any the worse for having been below the water, but he smiles and, shaking his head, he tells us that this is not the same forest. The forest which we saw before is now buried and rotting in the ground beneath this one. As he turns the picture away from this forest, we notice that it, too, is disappearing below the water. He promises to show us this same place by and by, and says that none of us will recognize it when he does come to it.

We have just been remarking that it seems strange to see the dry land without a living creature on it, when one of our party says that she sees a lobster going up on to the dry land. It is not a lobster, but a scorpion, and when it comes nearer we see a whole family of young scorpions clinging on to it. At the time represented by our picture, these scorpions had the whole dry land to themselves.

As the moving picture proceeds, we see different kinds of animals on the land, and we are not altogether surprised to see that some of these can live under the water or on dry land as they please, for we know that frogs and seals can do this to-day.

A very little girl in our party is frightened as a huge animal, with a long neck and a very long tail, walks

slowly into the picture. Here comes another animal, which not only looks fierce, but is fierce, for we see him catching a smaller animal and killing it. This big creature does whatever he likes; there are no hunters to kill him, for this is before the time when man was created.

We laugh as we see a heavy lizard trying to fly. It has never seen a bird fly, for there are no birds as yet. All this creature can do is to make a sort of running jump, supporting himself in the air with a pair of wings made of skin, and stretched over his front legs. Later on, however, we see some of his descendants flying quite long distances.

Then we see a curious-looking animal, and one of our party asks if it is a beast or a bird, but he is rather puzzled himself. It looks partly like a bird, and partly like a lizard. It has some feathers, but it has teeth, and it has claws at the corner of its wings, and it has a long tail like a lizard. A little later we have no difficulty in recognizing some real birds.

Some one says he sees a dog in the next picture, but the operator explains that it is not a dog at all; it is the animal from which our horses are descended. Look at his five toes, and his short neck, and his small head, and his arched back; he certainly does not look the least like a horse, and he is no bigger than a fox terrier.

We are watching the antics of some monkeys called gorillas, and we are interested to see a tribe of these making their way across the country where there are no trees; but the operator hurries on to another part, in which we shall see some of the first people who lived on the earth.

We are not surprised to see that these people have no clothes on, but we are a little surprised to see that they have quite a coat of hair over their bodies, and they seem to be making signs to each other.

The next picture shows some people wearing animals' skins tied round them. The men are busy with stone hammers and saws, and one woman is sewing skins together with a bone needle.

The picture suddenly shows the inside of a cave. At first we cannot see what is going on, as there is only one light from a stone lamp, and it is a great contrast to the daylight outside. In a little while we notice that one man is busy drawing a picture of an animal on the ceiling of the cave, and we can see other pictures or paintings on the walls.

We wait to see the family party at dinner, and we find that it consists of a piece of a huge woolly elephant called a mammoth. We notice that all the cutting is done with stone knives. From the great number of flint arrowheads lying about, it is quite evident that these people are great hunters.

As the moving picture proceeds, we see that the descendants of these primitive people are wearing more clothes. They have a coarse cloth, and we find one crossing the picture with an earthenware jug in his hand. Up to this time all the dishes that we have come across have been made of stone.

We follow this man, as we are anxious to see if the people still live in caves. He is evidently hurrying because it is getting late. He runs to the edge of a lake, keeping a sharp lookout among the long grass, as though

he were frightened. He is really frightened in case he should meet a wild beast. There, in the evening light, we see a village of huts built on supports right over the water of the lake. The village forms a little island, but it is near the shore. We watch the man calling, and in a moment we see a sort of drawbridge being lowered. He scrambles on to this and enters the village, whereupon the drawbridge is hoisted out of the way again. Now the man has no fear of the wild beasts that come down to the edge of the lake to drink.

The operator reminds us that it is time this picture show was over, but he will show us a few pictures of the world of to-day. He shows us one of the mining villages of Scotland, and there are the miners returning from their work with black faces and hands, and the little metal lamps on their caps. He tells us that this is where the great forests of giant ferns grew in the long ago, and he reminds us that the coal which these men bring up out of the earth is made of these forests which we saw in an earlier picture. It was here where these queer-looking mudfish and crocodile-like creatures used to live.

The next picture shows us some workmen building a railway on the Continent. They have to make some deep cuttings in the earth at this place, and we see the men busily examining some things which they have come across in their diggings. Here are some broken earthenware dishes, and some pieces of coarse cloth, and there are the bones of some animals, evidently sheep or goats. This is the same place at which we saw the lake-village. Thousands of years have passed, the lake

has dried up long ago, and these things which the railway engineers have found are the remains of the pile-villages of past ages.

While the operator has run all these things over for us very quickly, it really took millions and millions of years for all those changes to take place, for the things which happened in the pictures are things which we believe did happen in real life.

MY FIRST GEOLOGICAL EXCURSION

By Archibald Geikie

UP to that time my leisure hours, after school lessons were learned and all customary games were played, had been given to laborious mechanical contrivances, based sometimes on most preposterous principles. For a while I believed I had discovered perpetual motion. Day and night the vision haunted me of a wheel turning, turning, in endless revolutions; and what was not this wheel to accomplish? It was to be the motive power in every manufactory all through the country, to the end of time, to be called by my name, just as other pieces of mechanism bore the names of other inventive worthies, in that treasure of a book "The Century of Inventions." Among various contrivances I remember striving hard to construct a boat that should go through the water by means of paddles, to be worked by a couple of men, or, failing them, by a horse; but though I found (if my memory serve me) that my hero, the old Marquis of Worcester, had anticipated the invention by almost two hundred years, I could not succeed in getting the paddles to move except when the boat was out of the water, and so the grand contrivance that might have made its discoverer famous in every harbor in the kingdom, fell to the ground.

The Saturday afternoons were always observed by us as a consecrated holiday time, all school work being then

consigned to a delightful oblivion. To learn a lesson during these hours was regarded as something degenerate and wholly unworthy of the dignity of a schoolboy. Besides, we had always plenty of work of some kind to fill up the time, and what the nature of that work was to be for the ensuing Saturday had usually been determined long before the coveted Saturday came. Sometimes, if the weather was dull, my comrades repaired to my room (which we dignified as "the workshop") to hear a disquisition on the last invention, or to help if they could in removing some troublesome and apparently insuperable mechanical difficulty. Or we planned a glorious game of cricket, or golf, or football, that seldom came to a close until the evening grew too dark for longer play. In springtime we would sally forth into the country to some well-remembered bank, where the primroses and violets bloomed earliest, and return at dusk, bringing many a bunch for those at home. The summer afternoons often found us loitering, rod in hand, along the margin of a shady streamlet, in whose deeper pools the silvery trout loved to feed. And it fed, truly, with little danger from us.

Autumn brought round the cornfields, and the hedgerows rich in hip, and haw, and brambles and then, dear to the heart of schoolboy, came winter with its sliding, skating, and snowballing, and its long, merry evenings, with their rounds of festivity and plumcake.

'T is an old story, truly; but I remember as if it had been yesterday how my Saturday employments were changed, and how the vagrant, careless fancies of the schoolboy passed into the settled purposes that have

moulded the man. I had passed a Saturday afternoon alone, and the next day as usual met my comrades at church. On comparing notes, I found that the previous afternoon they had set out for some lime quarries, about four miles off, and had returned laden with wonders — plants of strange form, with scales, teeth, and bones of uncouth fishes, all embedded in the heart of the stone, and drawn out of a subterranean territory of almost fabulous extent and gloom. Could anything more marvelous have been suggested to a youthful fancy? The caverns of the Genii, even that of the Wonderful Lamp, seemed not to be more coveted. At least the new cave had this great advantage over the old ones, that I was sure it was really true; a faint suspicion having begun to rise that, possibly, after all the Eastern caverns might have no more tangible existence than on the pages of the story-book. But here, only four miles from my own door, was a real cavern, mysterious beyond the power of my friends to describe, inhabited by living men who toiled like gnomes, with murky faces and little lamps on their foreheads, driving wagons, and blasting open the rock in vast and seemingly impenetrable galleries, where the sullen reverberations boomed as it were for miles among endless gigantic pillars and sheets of Stygian water that stretched away deep and dark into fathomless gloom. And in that rock, wrapped up in its substance like mummies in their cerements, lay heaps of plants of wondrous kinds; some resembled those of our woods and streams, but there were many, the like to which my companions declared that even in our longest rambles they had never seen on bank, or brake, or hill;

— fishes, too, there were, with strong, massive scales, very different from our trouts and minnows. Some of the spiny fins, indeed, just a little resembled our foe the "beardie." Very likely, thought I, the Genius of the cave being a sensible fellow, has resolved to preserve his trout, and so with a murrain on the beardies has buried them bodily in the rock.

But above all, in these dark subterranean recesses lurked the remains of gigantic reptiles; and one of the quarrymen possessed a terrific tusk and some fragmentary scales, which he would have sold to my friends, could their joint purse have supplied the stipulated price.

My interest in the tale, of course, increased at every new incident; but when they came to talk of reptiles, the exuberant fancy could contain itself no longer. "Dragons! dragons!" I shouted, and rubbed my hands in an ecstasy of delight. "Dragons, boys, be sure they are, that have been turned into stone by the magic of some old necromancer."

So then and there we planned an excursion for the following Saturday. The days that intervened stretched themselves somehow to an interminable length. It seemed the longest week of my life, even though every sleeping and waking hour was crowded with visions of the wondrous cavern. At length the long expected morning dawned, and soon brightened up into a clear, calm autumnal day.

We started off about noon; a goodly band of some eight or nine striplings, with two or three hammers, and a few pence amongst us, and no need to be home before dusk. An October sun shone merrily out upon us; the

fields, bared of their sheaves, had begun to be again laid under the plough, and long lines of rich brown loam alternated with bands of yellow stubble up and down which toiled many a team of steaming horses. The neighboring woods, gorgeous in their tints of green, gold, and russet, sent forth clouds of rooks, whose noisy jangle, borne onward by the breeze, and mingling with the drone of the bee and the carol of the lark, grew mellow in the distance as the cadence of a far-off hymn. We were too young to analyze the landscape, but not too young to find in every feature of it the intensest enjoyment. Moreover, our path lay through a district rich in historic associations. Watch-peels, castles, and towers looked out upon us as we walked, each with its traditionary tales, the recital of which formed one of our chief delights. Or if a castle lacked its story, our invention easily supplied the defect. And thus every part of the way came to be memorable in our eyes for some thrilling event, real or imaginary — battles, stern and bloody, fierce encounters in single combat, strange weird doings of antique wizards, and marvelous achievements of steel-clad knights, who rambled restlessly through the world to deliver imprisoned maidens.

Thus beguiled, the four miles seemed to shrink into one, and we arrived at length at the quarries. They had been opened, I found, along the slope of a gentle declivity. At the north end stood the kilns where the lime was burnt, the white smoke from which we used to see some miles away. About a quarter of a mile to the south lay the workings where my comrades had seen the subterranean men; and there too stood the engine that drew

up the wagons and pumped out the water. Between the engines and the kilns the hillside had all been mined and exhausted; the quarrymen having gradually excavated their way southwards to where we saw the smoking chimney of the engine-house. We made for a point midway in the excavations; and great indeed was our delight, on climbing a long bank of grass-grown rubbish, to see below us a green hollow, and beyond it a wall of rock, in the center of which yawned a dark cavern, plunging away into the hill far from the light of day. My companions rushed down the slope with a shout of triumph. For myself, I lingered a moment on the top. With just a tinge of sadness in the thought, I felt that though striking and picturesque beyond anything of the kind I had ever seen, this cavern was after all only a piece of human handiwork. The heaps of rubbish around me, with the smoking kilns at the one end and the clanking engine at the other, had no connection with beings of another world, but told only too plainly of ingenious, indefatigable man. The spell was broken at once and forever, and as it fell to pieces I darted down the slope and rejoined my comrades.

They had already entered the cave, which was certainly vast and gloomy enough for whole legions of gnomes. The roof, steep as that of a house, sloped rapidly into the hillside beneath a murky sheet of water, and was supported by pillars of wide girth, some of which had a third of their height, or more, concealed by the lake, so that the cavern, with its inclined roof and pillars, half sunk in the water, looked as though it had been rent and submerged by some old earthquake. Not

a vestige of vegetation could we see save, near the entrance, some dwarfed scolopendriums and pale patches of moss. Not an insect, nor indeed any living thing seemed ever to venture down into this dreary den. Away it stretched to the right hand and the left, in long withdrawing vistas of gloom, broken, as we could faintly see, by the light which, entering from other openings along the hillside, fell here and there on some hoary pillar, and finally vanished into the shade.

It is needless to recall what achievements we performed; how, with true boyish hardihood, we essayed to climb the pillars, or crept along the ledges of rock that overhung the murky water, to let a ponderous stone fall plumb into the depths, and mark how long the bubbles continued to rise gurgling to the surface, and how long the reverberations of the plunge came floating back to us from the far-off recesses of the cave. Enough, that, having satisfied our souls with the wonders below ground, we set out to explore those above.

"But where are the petrified forests and fishes?" cried one of the party. "Here!" "Here!" was shouted in reply from the top of the bank by two of the ringleaders on the previous Saturday. We made for the heap of broken stones whence the voices had come, and there, truly, on every block and every fragment the fossils met our eye, sometimes so thickly grouped together that we could barely see the stone on which they lay. I bent over the mound, and the first fragment that turned up (my first-found fossil) was one that excited the deepest interest. The commander-in-chief of the first excursion, who was regarded (perhaps as much from

his bodily stature as for any other reason) an authority on these questions, pronounced my treasure-trove to be, unmistakably and unequivocally, a fish. True, it seemed to lack head and tail and fins; the liveliest fancy amongst us hesitated as to which were the scales; and in after years I learned that it was really a vegetable — the seed-cone or catkin of a large extinct kind of club-moss; but, in the mean time, Tom had declared it to be a fish, and a fish it must assuredly be.

The halo that broke forth from the Wizard's tomb when William of Deloraine and the Monk of St. Mary's heaved at midnight the ponderous stone was surely not brighter, certainly not so benign in its results, as the light that now seemed to stream into my whole being, as I disinterred from their stony folds these wondrous relics. Like other schoolboys, I had, of course, had my lessons on geology in the usual meager, cut-and-dry form in which physical science was then taught in our schools. I could repeat a "Table of Formations," and remembered the pictures of some uncouth monsters on the pages of our textbooks — one with goggle-eyes, no neck, and a preposterous tail; another with an unwieldy body and no tail at all, for which latter defect I had endeavored to compensate by inserting a long pipe into his mouth, receiving from our master ("Ironsides," we called him) a hearty rap across the knuckles, as a recompense for my attention to the creature's comfort. But the notion that these pictures were the representations of actual, though now extinct monsters, that the matter-of-fact details of our textbooks really symbolized living truths and were not invented solely to dis-

tract the brains and endanger the palms of schoolboys; nay, that the statements which seemed so dry and unintelligible in print were such as could be actually verified by our own eyes in nature, that beneath and beyond the present creation, in the glories of which we reveled, there lay around us the memorials of other creations not less glorious, and infinitely older, and thus that more, immensely more, than our books or our teachers taught us could be learned by looking at nature for ourselves — all this was strange to me. It came now for the first time like a new revelation, one that has gladdened my life ever since.

We worked on industriously at the rubbish heap, and found an untold sum of wonders. The human mind in its earlier stages dwells on resemblances, rather than on differences. We identified what we found in the stones with that to which it most nearly approached in existing nature, and though many an organism turned up to which we could think of no analogue, we took no trouble to discriminate wherein it differed from others. Hence, to our imagination, the plants, insects, shells, and fishes of our rambles met us again in the rock. There was little that some one of the party could not explain, and thus our limestone became a more extraordinary conglomeration of organic remains, I will venture to say, than ever perturbed the brain of a geologist. It did not occur at the time to any of us to inquire why a perch came to be embalmed among ivy and rose leaves; why a seashore whelk lay entwined in the arms of a butterfly; or why a beetle should seem to have been doing his utmost to dance a pirouette round the tooth of a fish. These ques-

tions came all to be asked afterwards, and then I saw how egregiously erroneous had been our boyish identifications. But, in the mean time, knowing little of the subject, I believed everything, and with implicit faith piled up dragon-flies, ferns, fishes, beetle-cases, violets, seaweeds, and shells.

The shadows of twilight had begun to fall while we still bent eagerly over the stones. The sun, with a fiery glare, had sunk behind the distant hills, and the long lines of ruddy light that mottled the sky as he went down had crept slowly after him, and left the clouds to come trooping up from the east, cold, lifeless, and gray. The chill of evening now began to fall over everything, save the spirits of the treasure-seekers. And yet they too in the end succumbed. The ring of the hammer became less frequent, and the shout that announced the discovery of each fresh marvel less often broke the stillness of the scene. And, as the moanings of the night wind swept across the fields, and rustled fitfully among the withered weeds of the quarry, it was wisely resolved that we should all go home.

Then came the packing up. Each had amassed a pile of specimens, well-nigh as large as himself, and it was of course impossible to carry everything away. A rapid selection had therefore to be made. And oh! with how much reluctance were we compelled to relinquish many of the stones, the discovery whereof had made the opposite cavern ring again with our jubilee. Not one of us had had the foresight to provide himself with a bag, so we stowed away the treasures in our pockets. Surely practical geometry offers not a more perplexing prob-

lem than to gauge the capacity of these parts of a schoolboy's dress. So we loaded ourselves to the full, and marched along with the fossils crowded into every available corner.

Despite our loads, we left the quarry in high glee. Arranging ourselves instinctively into a concave phalanx, with the speaker in the center, we resumed a tale of thrilling interest, that had come to its most tragic part just as we arrived at the quarry several hours before. It lasted all the way back, beguiling the tedium, darkness, and chill of the four miles that lay between the limeworks and our homes; and the final consummation of the story was artfully reached just as we came to the door of the first of the party who had to wish us good-night.

Such was my first geological excursion — a simple event enough, and yet the turning-point in a life. Thenceforward the rocks and their fossil treasures formed the chief subject of my everyday thoughts. That day stamped my fate, and I became a geologist.

HOW SOIL IS MADE

By N. S. Shaler

THE most important result of this battle that is waged against the rocks by the air, rain, etc., is the chance it gives for life to find a place on earth. All the vegetable life of the land depends upon the existence of soils, and all the animal life would have no chance to exist if it were not for the plants. Indeed, much, if not the most of the life of the sea is fed by the things the soil produces.

In any field we have one of the common shapes which this layer of earth takes on the earth's surface. If we look at it closely, we see that there is on the top a layer of a very dark color, which we at once know has its color given to it by the decayed plants it contains. These plants turn black as they rot; and, though they break up into small bits, we can still see on the surface that they are bits of plants. This is plain, for the plants are not altogether decayed, and keep their shape. As we go downward, these bits of dead plants gradually pass into a brownish mould. As we dig yet deeper, this disappears, and we have the earth without any mixture of plant-fragments, but only colored by the stain of decayed plants. As we go yet farther down, the soil becomes harder, until we come to the rock. This rock is generally soft at the top, and broken up by the roots

that work into it. Below this level it is found to be quite solid.

This is the common sort of soil over all the world, except on certain regions, of which we shall speak presently. Such a soil is made by the gradual decay of the rock. If we should strip it all away down to the solid rock, it would begin to form again in the following way: After a few years' exposure to the air, the stone would decay a little, and the seeds of lichens falling upon it would find a little softened rock to fix themselves upon. These simple plants need no soil, for they have no roots; they only need a roughened stone to fix themselves upon. They soon make a close net over the surface, so that it is quite hidden from sight. They keep the surface moist, and the acids made in the water by their decay help to rot the stone. Soon there is a little earth gathered in the small hollows of the rock; and in these, grasses and low shrubs find a foothold. These, with their roots, help to break up the decaying stones, so that they rot the faster. It takes many years, perhaps centuries, to make this beginning. These larger plants, when they die, make a mould that grows thicker and thicker as time goes on, so that it comes to be fit for the roots of trees. The seeds of pines, poplars, willows, and other trees with seeds so small that they need little covering, and so light that they can be carried by the wind, are constantly trying to find places to grow; and, as fast as this soil grows thick enough for their use, they spring up upon it. Soon we have the beginning of a forest, which is at first very stunted, because the soil is so thin. But this soil now grows rapidly in two ways: first, by the decay of the

leaves of the trees, as well as by their trunks and branches when they died; and, secondly, by the action of the roots, as well as of the frosts, in breaking up the stones at the bottom, so that they may rot the faster. The breaking up of the stones helps the rotting by adding to the surface over which decay goes on. If we have a solid mass of rock like a floor, it rots only over its surface; if it breaks up into bits, the surface over which the decay goes on may be ten or twenty times as large, and the decaying equally increased in rate.

All the while the rock is breaking up into bits in this fashion, the rain water is washing through it, becoming soaked full of acids as it passes through the decaying bed of leaves, and with them dissolving the rock into its waters. In this shape the substances of the soil are ready to be taken into the plant through its tender roots. If the plants are numerous, and the water goes slowly through the soil, a good deal of this stuff the water takes into solution is caught up by the plants into their bodies, and for a while rests above the soil in the light of the sun. By and by it falls by death, decays, and the ceaselessly acting water has another chance to drag it down with it to the sea. All the water that runs from the ground in springs takes some part of this plant food with it which the soil never recovers; but, while it robs the soil of a part of its richness, it gives more than it takes, by its effect in helping the decay of the rocks.

The richness of soil depends upon two things: first and foremost, on the nature of the rock below it, that is, to say, on the kind of substances that the rock has in it. If the rock be a limestone with a great many fossils, it is

sure to do its part of the soil-making in a perfect way, and give a fertile earth. Next, the soil depends on the action of the plants which yield it the vegetable matter, without which the rocks alone could not make the soil rich, for it is the acids that the water gains from the decaying plants that enable it to dissolve a sufficient part of the materials, so that the plants can get a hold on them. Of all the mass of a soil, probably not more than the thousandth part is at any one moment ready for plant food. The greater part stays undissolved, and it only slowly goes into the shape of food for the plants.

Let us see now what is done when man comes to use the soil for the crops on which depend all his arts. The rudest savage ranges through the forest, and takes only its fruits and its wild animals; but such peoples are rare. Almost every tribe in the world gets some profit out of the soil by tillage. This can only be done by stripping away the natural plants, and using their place for those which suit man's need. On the perfection of his methods in this work depend all his chances of civilization and wealth; for, however much wealth and culture are at times separated from agriculture, they always have their roots in this art, even as the trees, however high, depend on the earth beneath. When he tills the soil, man destroys its old natural state, and makes all its processes somewhat unnatural. When the plants are stripped away, the rain no longer does the same work of creation alone, but it becomes a destroyer. The sponge-like mass of dead leaves, twigs, and trunks that make up a forest bed, holds the running water away from the soil, until it gets into considerable streams. These generally

cut down into the rock, and so harm the soil but little — they eat only a little away along the river-banks. When the soil is tilled, the rain strikes on the surface of the bare earth, and sweeps great quantities into the streams. If the hills be steep, we often see the whole soil upon them carried away, leaving the bare rock, thus destroying in a few years the slow work of ages. When the soil is upturned by the plough, it is left very open, so that the process of decay goes on rapidly, and it is possible for a great deal of the soil to come into the shape for plant food; but the rain is the more able to bear it away, and so the soil loses many things that are necessary for plants. Now the crops take away much of the rarer kinds of substances that are necessary for plant life. While soils are always gaining in depth and fertility when in their natural crop of grass or forests, they are always becoming less deep and less fertile under ordinary tillage. The result is that a great deal of the soil of the earth that once was very fertile has been ruined by the plough. A skillful agriculture, that takes pains that the rains do not wash the soils away, nor the crops take away more than the natural work of decay puts into a state for plant food, may be maintained with little loss of the earth's fertility for thousands of years. In England, France, and Belgium, where the soils have been carefully husbanded, they yield as much to the acre as they did a thousand years ago or more; but in America the tillage is generally very careless, because soils are cheap, and a great deal of the land is ruined, to the permanent loss of all the world in this and in ages yet to come.

It is worth while to look closely to this matter of soils,

for on them depend the future of all countries and the life of man.

While the process of soil-making which we have described is the method that is followed wherever the soil is constructed on solid rock, there are other and rarer methods followed in particular parts of the earth. Along the river valleys, for instance, there is a strip of what is called alluvial land, which has been made by the earth brought down by the stream. This consists of a very deep mass of finely divided sand, pebbles, and mud, and in it the plants have no hard task of breaking up the rock, nor do they have to wait for the work of the forest, or other decay; for the amount of finely divided matter is so great, and the layer so deep, that the plants never get to the bottom of it. Indeed, this matter of the alluvial lands is, for the most part, the soil that has been washed away from regions farther up the stream, and left here because the river had more to carry than it could manage to bear along. Such soils are almost inexhaustible. Then, in the regions where the ice of the glacial sheet has acted, there are large tracts that are covered by a great thickness of sand and gravel, so that the plants never get access to the bed rock, and have not to wait long for the decay to form the materials out of which to make a soil. These soils are generally less fertile than the other lands; but, because of the great depth of the substances of which they are made, they rarely become less fertile than they were at first. Thus, the New England soils cannot be worn out as those of South America or Virginia, although in the first place they were not so rich.

We may gather up this account of soils in the following words: Soils are the wreckage of the rocks, as they wear down under the action of air, rain and frost, the roots of plants, and the stomachs of earthworms. This wearing has been going on for a very long time in the past, so that the soil now on any country may have gradually settled downwards for thousands of feet, as the rocks slowly rotted away and were carried off by the streams. It is a beautiful fact that the greatest work of ruin that the world knows — the decay of the continents themselves — should give us the foundations on which to rest all the higher life of the world. All our forests and prairies owe their life to this decay. All the higher animals of the world depend upon this plant life, and man himself founds his life upon the same mass of ruin. Thus it is through all the life of the world: the death of one thing gives life to others; the decay of the physical world is the foundation for the higher life of plant and animal.

THE WORK OF MUD

By Alexander Winchell

NOT far from the home of my boyhood was the mill-pond, dear to every schoolward-trudging urchin who had to pass it, and a Saturday resort for many others who lived in the adjoining "district." Here we bathed; here we fished; here we risked our lives in shaky skiffs and astride of unmanageable logs. The water was deep and clear. Last summer I visited the old pond. The scene of so much truant enjoyment was changed almost beyond recognition. The deep, clear water was silted up, and flags were thrusting their brown noses up, in the sites where I used to swim in summer and skate in winter. Sedges fringed the borders; bulrushes, to their knees in water, were holding possession of land that was expected to be, and the encroaching marsh threatened to corner the anxious perches and sunfishes in the last lingering bowl of clear water close by the decrepit old dam. This, I thought, is a picture of the history of the world. How long, I queried, before this mill-pond will be a swamp? Is this the impending fate of all our ponds and lakelets?

The first land surveyors of the territory of Michigan had down on their plats an extraordinary number of swamps and bogs. It is true they greatly overdid the swamp-land business; but swamps are there in plentiful abundance; and swamps properly drained and tilled are

the richest lands in the State. But the early settlers of Michigan found many of the swamps nonexistent; some were grassy plains; some were quaking bogs, and others were part marsh and part lakelet. During sixty years many of the quaking bogs have become solid meadows; and many of the marsh-side lakelets have totally disappeared, under the encroachments of the growing marsh. These are geological changes, and the geologist's eye looks about for the causes. It is not a far-fetched solution to see in the hillside wash a source of silt, which annually diminishes the depth of water to a certain extent. And it requires but ordinary sagacity to notice each decaying crop of grasses, sedges, and rushes as the source of the dark peaty deposit which displaces the last water, when other causes have produced the requisite shallowness. We have caught the marsh-making business in the midst of its accomplishment. Short as our lives are, each life falls within the geologic age in which vast results are actually working out. All these marshes have been lakes. If we dig in them we find the bleached relics of the very shells which held animated tenants of the vanished lakelet. Thus, gathering sediments add sheet after sheet to the deposits which are filling the larger as well as the smaller bodies of water which rest on the earth's surface.

All great rivers are enormous mud-carriers. The Nile, the Amazon, the Ganges, the Hoang-ho, the Mississippi, are great vehicles for the transport of earthy substances from the higher to the lower levels. Like the Tiber, their waters are all "yellow." What a potion is a glass of Mississippi water, placed by the side of one's plate

in the cabin of the steamer! In thirty minutes it holds a deposit of impalpable sediment, which is simply mud. Think of the entire breadth and depth of this mighty stream charged with earthy materials to such an extent. What must be the total amount of matter carried down to the Gulf annually? The engineers of the United States have attempted to answer this question. They say that if the annual discharge of mud were brought together and dried, it would form a block a mile square and two hundred and seventy-eight feet high. Imagine that block lying on the surface of some level township. Then think another block on the top — the result of another year's transport. Recall the fact that the Mississippi has been at this business at least five or six thousand years. Put five or six thousand such blocks together; the aggregate would be a mountain range.

There are seasons when the proud river climbs over its bounds — climbs over the artificial restraints which have been imposed in the form of *levees*. Water and mud spread over hundreds of plantations. Then, as in the overflowing torrent of the Aar, the slackened motion of the water allows the fine sediment to subside. Corn lands and cotton lands receive a new contribution of fertilizing material. Such service the Nile performs for Egyptian agriculture — under the rule of the Khedives, as during the reign of the Pharaohs. Thus the deltas of the great rivers are formed. Still the great preponderance of river silt passes on to the outlets. Not only the floating sediment, but a large amount of bottom mud, too thick to float and too loose to lie unmoved. This the stream

pushes along into the sea — year by year into deeper and deeper water, as the shallower shore region becomes silted up. This is the bar. By the annual extension of the bar, the delta gradually protrudes a tongue of land into the sea. Look at a map of the mouth of the Mississippi, or the Nile, or the Ganges. Often the piled-up bar material so obstructs the exit through the main channel, that the water sets back up the stream during some flood, overflows its banks, and seeks a new route to the sea. This may be many times repeated. So these great rivers acquire numerous outlets. Look at the map again. The bar at the mouth of the Mississippi extends three hundred and thirty-eight feet into the Gulf annually.

Much of the Mississippi sediment, therefore, lies somewhat permanently on the Gulf bottom, near the shore. Through this Engineer Eads staked out a channel to which the current of the Mississippi is confined after entering the Gulf, until deep water is reached. Its velocity is thus preserved, and its mud is carried beyond into the deeper basin. Before this improvement, the water spread out fan-like, and slackened its velocity to such an extent that the mud was deposited in a region where the water was already so shallow that navigation became seriously obstructed.

Still, some of the sediment floats on beyond the bar. There is a current in the Gulf which sets eastward along the northern border, and bears Mississippi sediment as far as the straits of Florida. The fine impalpable dust finally comes to rest on the bottom of the Gulf.

A thousand rivers thus are bringing their contribu-

tions to the sea. Around ten thousand miles of coast, the sea itself is battering down the land. The coarser fragments are left along the beach. The enfeebled action of the retreating surf bears some distance seaward the smaller fragments and the pebbles — rolled and rounded on the beach. The finest sediments have no opportunity to subside till floated far from shore. Thus the same assortment is exerted which we saw effected by the torrent of the Aar. The ocean's bottom lies covered to a vast extent with sheets of sedimentary materials which, near the shore, are coarse, and remoter from shore are progressively finer, as far as the finest sediments are floated. This process goes forward before our eyes; it has been continued during all the thousands of ages past, since the ocean first came into existence. How many layers must there be? How many feet of sediments have been piled up? What conditions have they assumed while the geologic æons have rolled by?

ABOUT PEBBLES

(*Abridged*)

By Charles Kingsley

IF we find spread over a low land pebbles composed of rocks which are only found in certain high lands, is it not an act of mere common sense to say, These pebbles have come from the high lands? And if the pebbles are rounded, while the rocks like them in the high lands always break off in angular shapes, is it not, again, an act of mere common sense to say, These pebbles were once angular, and have been rubbed round, either in getting hither or before they started hither?

Next, if you will examine the pebbles carefully, especially the larger ones, you will find that they are not only more or less rounded, but often scratched; and often, too, in more than one direction, two or even three sets of scratches crossing each other; marked, as a cat marks an elder stem when she sharpens her claws upon it; and that these scratches have not been made by the quarrymen's tools, but are old marks which exist — as you may easily prove for yourself — while the stone is still lying in its bed of clay. Would it not be an act of mere common sense to say, These scratches have been made by the sharp points of other stones which have rubbed against the pebbles somewhere, and some when, with great force?

So far so good. The next question is, How did these

stones get into the clay? If we can discover that, we may also discover how they were rounded and scratched. What, then, brought the stones?

They may have been rolled hither by water. That theory would certainly explain their being rounded; though not their being scratched. But it will not explain their being found in the clay.

Water drops its pebbles and coarser particles first, while it carries the fine clayey mud onward in solution, and only drops it when the water becomes still. Now currents of such tremendous violence as to carry these boulder stones onward, would have carried the mud for many miles farther still; and we should find the boulders, not in clay, but lying loosely together, probably on a hard rock bottom, scoured clean by the current. That is what we find in the beds of streams; that is just what we do not find in this case.

But the boulders may have been brought by a current, and then the water may have become still, and the clay settled quietly round them. What? Under them as well as over them? On that theory also we should find them only at the bottom of the clay. As it is, we find them scattered anywhere and everywhere through it, from top to bottom. So that theory will not do.

Now, suppose that there was a force, which is at work over the vast sheets of land at both the North and South Poles; at work, too, on every high mountain range in the world, and therefore a very common natural force; and suppose that this force would explain all the facts, namely — how the stones got here; how they were scratched and rounded; how they were embedded in

clay; because it is notoriously and before men's eyes now, carrying great stones hundreds of miles, and scratching and rounding them also; carrying vast deposits of mud, too, and mixing up mud and stones just as we see them in the brick pits — would not our common sense have a right to try that explanation? — to suspect that this force, which we do not see at work in Britain now, may have been at work here ages since? What state of things, then, do we find among the highest mountains; and over whole countries which, though not lofty, lie far enough north or south to be permanently covered with ice?

We find, first, an ice-cap or ice-sheet, fed by the winter's snows, stretching over the higher land, and crawling downward and outward by its own weight, along the valleys, as glaciers.

We find underneath the glaciers, first a *moraine profonde*, consisting of the boulders and gravel and earth, which the glacier has ground off the hillsides and is carrying down with it.

These stones, of course, grind, scratch, and polish one another; and in like wise grind, scratch, and polish the rock over which they pass, under the enormous weight of the superincumbent ice.

We find also, issuing from under each glacier, a stream, carrying the finest mud, the result of the grinding of the boulders against one another and the glacier.

We find, moreover, on the surface of the glaciers, *moraines supérieures* — long lines of stones and dirt which have fallen from neighboring cliffs, and are now traveling downward with the glaciers.

Their fate, if the glacier ends on land, is what was to be expected. The stones from above the glacier fall over the ice-cliff at its end, to mingle with those thrown out from underneath the glacier, and form huge banks of boulders, called "terminal moraines," while the mud runs off, as all who have seen glaciers know, in a turbid torrent.

Their fate, again, is what was to be expected if the glacier ends, as it commonly does in Arctic regions, in the sea. The ice grows out to seaward for more than a mile sometimes, about one eighth of it being above water and seven eighths below, so that an ice-cliff one hundred feet high may project into water eight hundred feet deep. At last, when it gets out of its depth, the buoyancy of the water breaks it off in icebergs, which float away, at the mercy of tides and currents, often grounding again in shallower water, and ploughing the sea-bottom as they drag along it. These bergs carry stones and dirt, often in large quantities; so that, whenever a berg melts or capsizes, it strews its burden confusedly about the sea-floor.

Meanwhile the fine mud which is flowing out from under the ice goes out to sea likewise, coloring the water far out, and then subsiding as a soft tenacious ooze, in which the stones brought out by the ice are embedded. And this ooze cannot be distinguished from the brick clay, or fossiliferous boulder clay, so common in the North.

Let us go a step farther, and, bearing in our minds what live glaciers are like, let us imagine what a dead glacier would be like; a glacier, that is, which had

melted, and left nothing but its skeleton of stones and dirt.

We should find the faces of the rocks scored and polished, generally in lines pointing down the valleys, or at least outward from the center of the highlands, and polished and scored most in their upland, or weather sides. We should find blocks of rock left behind, and perched about on other rocks of a different kind. We should find in the valleys the old moraines left as vast deposits of boulder and shingle, which would be in time sawn through and sorted over by the rivers. And if the sea-bottom outside were upheaved, and became dry land, we should find on it the remains of the mud from under the glacier, stuck full of stones and boulders, iceberg-dropped. This mud would be often very irregularly bedded; for it would have been disturbed by the ploughing of the icebergs, and mixed here and there with dirt which had fallen from them. Moreover, as the sea became shallower and the mud-beds got awash one after the other, they would be torn about, resifted, and reshaped by currents and by tides, and mixed with shore-sand ground out of shingle beach, thus making confusion worse confounded. A few shells, of an Arctic or Northern type, would be found in it here and there. Some would have lived near those later beaches, some in deeper water in the ancient ooze, wherever the iceberg had left it in peace long enough for sea-animals to colonize and breed in it. But the general appearance of the dried sea-bottom would be a dreary and lifeless waste of sands, gravels, loose boulders, and boulder-bearing clays; and wherever a boss of bare rock still

stood up, it would be found ground down, and probably polished and scored by the ponderous icebergs which had lumbered over it in their passage out to sea.

In a word, it would look exactly as vast tracts of the English, Scotch, and Irish lowlands must have looked before returning vegetation coated their dreary sands and clays with a layer of brown vegetable soil.

Thus, and I believe thus only, can we explain the facts connected with these boulder-pebbles. No agent known on earth can have stuck them in the clay save ice, which is known to do so still elsewhere.

No known agent can have scratched them as they are scratched, save ice, which is known to do so still elsewhere.

No known agent — certainly not, in my opinion, the existing rivers — can have accumulated the vast beds of boulders which lie along the course of certain northern rivers, save ice, bearing them slowly down from the distant summits.

No known agent, save ice, can have produced those rounded, and polished, and scored and fluted *rochers moutonnés* — "sheep-backed rocks" — so common in the Lake district [and elsewhere]; to be seen anywhere around the Scotch Highlands, where the turf is cleared away from an unweathered surface of rock, in the direction in which a glacier would have pressed against it had one been there. Where these polishings and scorings are found in narrow glens, it is, no doubt, an open question whether some of them may not be the work of water. But nothing but the action of ice can have produced ice-flutings in polished rocks below high-water mark, so

large that I could lie down in one of them. Nothing but the action of ice could produce what may be seen in any of our mountains — whole sheets of rock ground down into rounded flats, irrespective of the lie of the beds, not in valleys, but on the brows and summits of mountains, often ending abruptly at the edge of some sudden cliff, where the true work of water, in the shape of rain and frost, is actually destroying the previous work of ice, and fulfilling the rule that ice planes down into flats, while water saws out into crags and gullies; and that the rain and frost are even now restoring Scotch scenery to something of that ruggedness and picturesqueness which it must have lost when it lay, like Greenland, under the grinding of a heavy sheet of ice.

Lastly; no known agent, save ice, will explain those perched boulders, composed of ancient hard rocks, which may be seen in so many parts of these islands and of the Continent. No water-power could have lifted those stones, and tossed them up high and dry on mountain ridges and promontories, upon rocks of a totally different kind.

Thus, I think, we have accounted for facts enough to make it probable that Britain was once covered partly by an ice-sheet, as Greenland is now, and partly, perhaps, by an icy sea.

HOW CAVES ARE MADE

By N. S. Shaler

THE greater part of the work done by water is done above the ground; but there are certain peculiar effects it has, when it works below the surface, that have much interest for us.

When water falls as rain, a part of it flows at once away to the streams, and a part penetrates into the earth. That which goes below the surface creeps slowly through the earth until it is either sucked up by the plants or escapes into the springs. This underground water that is going toward the springs generally cuts for itself little imperfect channels, by dissolving away the soil so as to make a natural drain, which we imitate when we put pipes under a field for drainage. But these springs that do not have their channels below the level of the soil are always very small, and last only during wet weather. When we find a spring with a strong stream of water, we may be sure that it comes out of the earth from below the level of the soil after a journey through the underlying rock. The question arises, how does it manage to make a passage through this rock. These rock passages of the underground waters are sometimes among the most wonderful of the works that water makes. If the rock be one that water cannot easily dissolve, such as sandstone, claystone, pudding stone, granite, etc., the only chance for water to make springs

is to get deep into it through some rift or break in the mass of rock. These are not often found. The result is that such springs are rarely found in regions underlaid by rocks of this sort. The most of the surface of New England, for instance, is almost destitute of good springs because it is generally underlaid by very hard rocks. When, however, the underlying rock is limestone, we generally have very many large rock springs that carve out for themselves great underground channels called caverns. These caverns are of very different sizes, sometimes being small tube-like openings that are hardly large enough for the swollen waters in times of rain. These occur when the limestone rocks are bedded with strata, like claystones between, that are not to be dissolved by the water. When, however, the beds of limestone are thick and without these clay partings, the caverns may become very large indeed.

Perhaps the largest of these limestone caves are found in Kentucky, where there is a region containing about eight thousand square miles of country that is completely honeycombed with them. Some of these, such as the Mammoth Cave, are so vast that we may walk for days through passages that are often thirty feet or more high and fifty feet wide. Underground rivers and waterfalls, chambers beautifully ornamented with wonderful stalactites and stalagmites, and a great number of animals that live in the cavern and nowhere else, make these chambers quite an underground world, where everything differs from the daylight region.

The way these caverns are formed can easily be seen by studying what is now going on in the country where

they occur. This Kentucky cavern district lies in an elevated, level region, where the rocks have never been tilted about, but stay in much the same position as that in which they were made on the sea-floors, before the coal time. When we journey over this country, we see that only the large streams appear at the surface of the ground. These flow in deep gorges, with steep cliffs on either side. The smaller streams do not flow on the surface. They come into the main rivers through cavern mouths, that often lie below the level of the water, along these greater streams.

The surface of the country between these rivers has no valleys in it, such as have the streams in most parts of the earth, but is arranged in circular shallow pits, called "sink-holes." Of these there are often several dozen in a square mile of fields. All the water that runs off the surface in a rain goes into these sink-holes, and flows down into the earth through a small, ragged tube that descends from the center of the pit. We can often hear it in times of heavy rain running down into the depths of the earth. Some of these sink-holes have large openings, so that a brave explorer can be lowered down into the underground course of the water. In this way we can see the whole course of the cavern making. The entrance from the open air is generally very narrow, but with various irregularities. The opening widens until it is sometimes as much as fifty feet from wall to wall. Whenever there is a strong shelf of rock, there are generally level passages leading off into the distance toward the lower mouth of the cave. We may pass several of these in the descent. When we arrive at the

bottom, we find a pit generally full of water, and by its side another horizontal passage leading off into the darkness.

In the bottom of this vertical chamber or "dome," if we look closely, we see many bits of flint and other hard stones. They are not a very striking feature of the cavern, but they are the key to a part of its work. We must now conceive what happens in wet weather, when down this deep shaft the water rushes with very great force. These hard stones are then driven like miners' drills against the rock, and they speedily cut up the soft limestone. The lime is easily carried away by the stream through the side passage. The bits of flint themselves are found in the limestone rock. We can often see them sticking out of the walls, and the Indians were in the habit of coming to these caves to get such flints for their arrowheads.

Entering into the side galleries that open out of this dome, we find that they lead off horizontally for great distances; sometimes, as in the great avenues of the Mammoth Cave, we can walk through a passage as large as the aisle of a cathedral for four or five miles. Each of these side passages or galleries gave a way for the water out to the air, at the time when the dome had not cut deeper than down to the level of the floor of the particular gallery. The domes of these caverns are sometimes wonderfully grand. The walls are sculptured by water into fantastic likenesses of columns. When lighted with bright fires, it is hard to believe that we are not looking upon some supernatural work. The galleries, if less grand, are more beautiful, and in them are found the

finest specimens of those stalactites that are the chief ornament of these underground chambers.

These singular structures are of the most varied forms. Sometimes they are like flowers, clustering over the ceilings, and shining in the light of the torches; again, they are like the trunks of trees growing from the floor to the ceiling. Sometimes they appear like fountains; again, like sculptured monuments; but always decorated with strange tracery. If we search the cavern, we can find how these singular forms are made. Choosing a place where the roof of the cave is low, we can see that the water slowly trickles through the ceiling, and falls, drop by drop, to the floor. This water comes slowly; each drop glistens awhile on the ceiling before it falls; during this time, when it is still, some of the carbonic dioxide gas escapes from it, and a part of the lime it holds is laid down on the ceiling. We can often see the very beginnings of a little hanging cone formed in this way. Gradually this cone grows until it hangs halfway to the floor of the cave. When the drops fall, they splash out and evaporate in the dry air of the cave, leaving the rest of their lime in a little heap on the floor. This heap grows upward toward the cone that builds down from the ceiling, until at length they are united. Now the drops no longer fall, but creep down the sides of the unbroken column, evaporating as they go, leaving their lime on its sides. And so the mass of stalactites constantly grows larger and larger. In time they fill the whole gallery; and in this way, after centuries, this passage of the cavern is destroyed. It is only when the ceiling of the cave is so close that water cannot trickle

through it, that this process does not in course of time fill the whole space with stalactite.

The bottom of these caves can never be lower than the neighboring river, where the underground waters are discharged. As the river cuts deeper into the rocks that form its bed, the domes work farther down into the rock, and new and lower galleries are formed.

While this underground work is going on, the decay of the surface is going on also; so that the uppermost galleries are slowly destroyed. Their roofs grow thin and fall in, so that they are opened to the day. Now and then, parts of their ceilings hold on for a long time, and in this shape are called "natural bridges." All these natural bridges are the remains of great caverns. Some of the finest specimens known are found in Carter County, Kentucky, and Rockbridge County, Virginia.

This wearing-down of the caverns goes on for ages, so that over the place where the caves now are we may believe there have been many other caves, perhaps hundreds of feet in the air, where the earth once was, in the ages before the level of the ground was worn down to its present position.

To the students of nature these caverns are full of interest. First, they show to them the wonderful dissolving power of water when it runs through limestone rock. They also contain many strange forms of animal life. Some of the outside animals use these caves as places of shelter. The bears that sleep through the winter often resort to caves for shelter; and during the winter season, great numbers of bats are found in them. These bats are often to be seen hanging from the ceil-

ings in great bunches, one grasping on another, the topmost holding to the roof. They are asleep, and for all the winter-time hang motionless, as if dead. When the springtime comes, though the temperature of the air does not change in the least, they know in some way that their time for waking has come; their stagnant blood begins again to flow freely, the heat of their bodies returns, and forth they go to the open air again.

Besides the many creatures that use the caverns as a place of occasional resort for shelter, there are many animals that live their whole lives in this perpetual darkness. There are certain fishes which are found there and nowhere else; these species have lost not only their sight, but the very machinery of vision. Their eyes have disappeared, and a very delicate sense of touch in the parts about the head takes the place of the sight sense. The same thing occurs in many forms of insects and crayfishes. Their eyes also disappear, and their feelers become lengthened. These facts are not only curious, but they seem to show the close relation between the conditions in which an animal lives and the form and functions of its body. In this age, when naturalists are trying to find out the laws that have fixed the shapes and organs of living beings, these facts, revealed in the underground world, are of the utmost importance to science.

There are many other phenomena connected with caverns. We can notice only a few of them. If on a summer day we approach the mouth of a cave that opens low down on the cliffs near the stream, we perceive, even at some distance from the cavern's mouth, a strong wind that rushes out of the shadowy opening.

This wind is often so strong that it makes the ferns and bushes about the mouth sway to and fro. It is so cold that it sends a chill through us as we step into it from the heated summer air. The hotter the outer air, the stronger this blast from the cavern. In the last part of the night, when the outer air is cooler, the current becomes less strong. In winter it turns, and we then find a stream of air entering the cavern, that runs as briskly inward on cold days as it did outward in hot weather. From the sink-holes above the cavern, which connect with the domes, we feel the air pouring out in a strong stream. When the day is very cold, we see this warmer air of the cavern, which is somewhat moist, condensed in the cold outer air, so that it looks like steam. The reason for this movement is plain. In the summer time, the air in the cavern is much colder than that in the open, and, being colder, is much heavier; it therefore flows out at the lowest opening of the cave. There is then a current of warm air setting down through the sink-holes into the cavern. The cold rocks there soon cool it, so that the blast from the mouth of the cavern is sustained. In the winter time, the cavern air is much warmer, and therefore lighter, than the open air; and so the cavern gives a current upward through the sink-holes, while it draws in through the mouth. This is the same law that rules the great circulation of the air from the equator to the poles. So vast are the interiors of these greater caverns, such as the Mammoth Cave, that, despite these constant currents into it, the temperature constantly remains the same, there hardly ever being a degree of difference between winter and summer.

It may be interesting to the student to know some facts concerning the use of these caverns by man. The Indians evidently traveled through most of them, for we find their footprints everywhere. The soft sand that fills many of the passages of these caves will preserve a footprint unchanged for many centuries, and so we can find the tracks of a people that vanished from this land a century ago, the print of the moccasin looking so fresh that it might have been made but an hour. We also find there torches which they made by filling hollow canes with grease, an arrangement that makes a very good torch. It is evident that some of these caves were used in times of war as places of retreat, for some of the remote chambers, that a stranger can hardly find his way to, were evidently lived in for a considerable time. In one or two cases the bodies of Indians have been found who had evidently wandered away, while seeking to find the way out, and were lost in the labyrinth of passages. These bodies have not decayed, but have dried like mummies in the air. The Indians also used these caves as places of burial. Sometimes the bodies were only thrown in through the sink-holes; in this case they were probably those of enemies slain on some battlefield. At other places we find the bodies carefully buried, with all their trinkets and tools about them, with the hope that those things might serve the dead in the long hereafter of plentiful hunting and war that their friends hoped for them.

The white men, too, have found use for caves. For many years they were worked for saltpeter. Much of that used in making gunpowder for the war with Great

Britain, in 1812–14, came from the Kentucky caves. Of late years other supplies have taken its place, and now the caverns are only a little used for growing mushrooms, and storing various fruits and vegetables that keep better in a uniform, rather dry air. This underground world will remain of use to man, by giving him a place in which he can find an utter change from the life of the surface; a pure air, as well as a weird and wonderfully beautiful scenery.

European caves have also been of great use to the geologist, from the fact that in them are preserved the remains of many animals that would otherwise be unknown to us. Many of these caverns are very old. Some of them have been in existence for the inconceivable time of a million of years or more. They were open in a day when other animals lived than those now on the earth. Some of these creatures used the caves for dwellings; others were swept into them by floods, or dragged in by beasts that preyed upon them. These remains have often become sealed up beneath the stalactites that form in the caves, and so have been preserved from decay. By a careful system of excavations it is possible for the geologist to get access to these remains, and from them to infer the character of the land life in times that would otherwise be unknown to him.

European caves contain more bones than American, because in the old days when they were formed hyenas and jackals abounded there. These creatures have the habit of dragging bones and dead bodies into caverns; and so they helped to stow away the remains of many animals which have ceased to live, and which would be

unknown to us but for the bones that are buried in the caverns.

Many of the historic remains of man, which go far back beyond the time of histories, have been found in the European caverns, mingled with the remains of animals that exist no longer.

There are some rarer sorts of caves that are not formed in the fashion of those in Kentucky. These are of three classes. The first very much resemble those of Kentucky in their general character and history; they are cut out of limestone by water, but the water is that of hot springs and not of the surface. This hot-spring water, ascending to the surface, may find limestone rocks in its path. In this case it generally dissolves out great chambers. Caves of this character are exceedingly irregular in their form. There are no domes, and, unlike surface caves, they may be formed below the level of the river into which their waters discharge. They are not very numerous, but exceedingly interesting on account of the valuable metallic deposits that they often contain. Some very important deposits of silver and gold ores occur in just such caves as these. The hot spring has first carved out the limestone, and then filled its space with ore.

The rarest, yet sometimes the most curious caves of all, are formed in lava streams. The flowing lava hardens on the top, because the air chills it and makes an arch over the stream; then the supply of melted rock failing, the stream sinks down and leaves this arch, causing a cave that reaches from the base of the volcano to the top. Suc[illegible] to the arches

formed over temporary streams by the sharp cold of a frosty night that follows a winter thaw. The flood sinks away, and leaves the roof of ice hanging in the air above the course that the waters have ceased to flow in. The next eruption of the volcano is apt to destroy this cave; but sometimes they endure for ages, being deeply buried beneath ashes and other lavas.

We may complete our account of caves by a brief description of those made on the seashores by the beating of the waves.

Wherever the coast is rocky and open to the wide water, the sea, in times of storm, hurls its waves with great power against the shore. If these waves held nothing but water, they, despite the fury of their blows, would not be able to wear the hard rocks to any great extent. But in most cases these waves have in their grip pebbles, or larger pieces of stone, which they hurl against the cliffs. Wherever there is a soft place in the rocks of the cliffs, the sea soon makes a wedge-shaped opening; into this opening the stones torn from the neighboring shore are collected, so that the waves have a constant supply of rocky fragments with which to batter the rocks. In this way they sometimes cut channels extending some hundreds of feet back from the sea front.

When the rocks of the shore have dykes or veins in them, these deposits are often softer than the rocks on which they lie, and so are excavated by the sea. All along the shores of New England we find many of these furrows, commonly called chasms. When the sea waves rush freely into these furrows, their spray is sometimes

during storms forced high into the air, when the crevice is commonly called a "spouting horn."

These caves worn by the sea are never very large, and have none of the beauty or interest that belongs to those made in limestone by the waters of the land.

WHY THE SLIDES SLIDE AT PANAMA

By J. F. Springer

WHILE the Panama Canal is by no means the longest in the world, — the Suez Canal is twice as long, — still the problems met and solved in its construction make it one of the truly great undertakings of the world. And yet, the conquest of the natural conditions is not quite complete. The slides in Culebra Cut are not only a continual menace to the continuity of operation, but, as the present situation proves, they may easily interrupt traffic for several months.

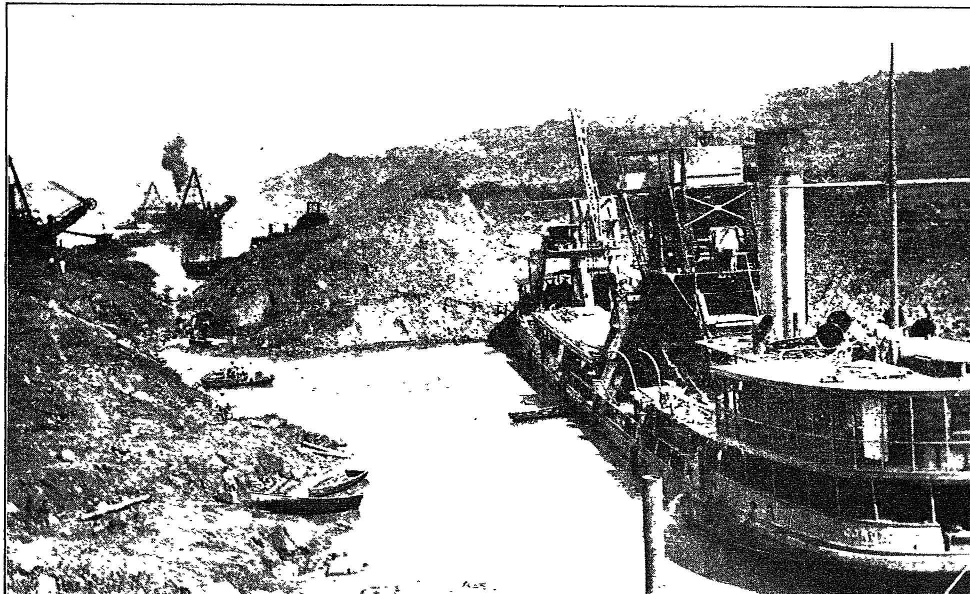
The canal pierces the continental ridge, at Panama only a few hundred feet in height and nine or ten miles in width. A V-shaped cut was made through this ridge and the canal located at the bottom of the V. It will be seen at once that there must be high slopes to either side. The slides occur because a mass on a slope loses its frictional grip on the underlying material, and slips — not necessarily with rapidity — on and down under the influence of gravitation. But "on and down" bring it at last into the canal itself. It may confidently be expected that in the course of time everything will have slipped and slid that is going to slip and slide; so that eventually the trouble will cure itself. No doubt the engineers put some dependence upon this consideration. If the slides could be counted upon to be moderate in their individual

attempts and to allow proper intervals between, then we might be content to await a condition of final equilibrium. But the canal was built for strategic and commercial purposes, neither of which can wait on so slow a process. And so General Goethals has resumed his control.

The Panama Canal, unlike that of Suez, is not a sea-level waterway. The main portion of the canal, from Gatun Locks in the north to Pedro Miguel Lock in the south, has its normal surface eighty-five feet above the sea level on the Atlantic side. This means that the bottom is some eighty-five feet higher than would be the case if the water simply flowed through from ocean to ocean. The canal was elevated to secure the advantage of not having to cut the V down to the low level necessary for a sea-level canal. Carrying the point of the V down to a level eighty or eighty-five feet lower would mean vast additional excavations on the sides of the V. So the canal was constructed on a high level.

The most notable of the slides is known as the Cucaracha. It is at least thirty years old, and began its activities long before the Americans took charge, during a long period of inactivity extending from 1889 to 1905, a period when but little was done in the way of excavation. The motion is frequently slow, amounting to no more than a few inches per hour. It probably moves more or less in all seasons.

But Cucaracha is by no means the only slide. In one year as many as thirteen slides were in movement in the region of Culebra Cut. Slides occur at all seasons of the year. The precise cause of a slide does not seem to be



DREDGING A SLIDE IN THE PANAMA CANAL

known with certainty. It is probable that some slides may be safely attributed to the slow tobogganing of soft surface material on hard, underlying rock sloping toward the canal. The cutting away of material on the lower edge may easily precipitate a general movement of the material above simply because a support has been removed.

The slides have other effects besides that of moving down into the canal. One night in March, 1913, a break on the eastern canal bank, opposite the town of Culebra, resumed an activity which began some weeks before. The excavated surface at the bottom of the canal near the center was lifted up for a distance of one thousand feet. This upheaval had a maximum elevation of as much as thirty feet. This phenomenon is due, no doubt, to a kind of see-saw action. The movement of material down towards the canal increased the weight at this point, which reacted against soft material underlying it and the canal bottom, so that the soft material was pressed down at one point, pushed up at another, thus forming a ridge in the bottom of the canal. At any rate, this seems a reasonable explanation of this and similar occurrences. The same slide repeatedly produced the phenomenon of pushing up the bottom of the canal.

There are two great slides near Culebra, one on the western bank and the other on the eastern bank. These two move toward each other and produce a double effect. They effect a length of canal channel amounting to more than half a mile. Both are north of the two ridges known as Gold Hill and Contractor's Hill, which face each other across the canal. The two slides comprise

an enormous total of slipping material. The estimate runs as high as nine million cubic yards. The limits of the movement are located at considerable distances back from the line of the canal. On the eastern side the break goes back to a line one thousand five hundred feet distant from the canal axis. On the western side the break is nearly as far back. The movements extend far up the slopes — in one case to a level two hundred and sixty-five feet above the canal surface and in the other to a level five hundred feet above. The material is being taken away at the bottom.

Cucaracha Slide may be counted on to be active at almost any time slides should be working. If the canal had been constructed as a sea-level waterway, these slides would probably have been still more active than they now are, because of the great opportunities with an added eighty-five feet of depth to Culebra Cut.

It seems doubtful whether the movements of earth and rock at Panama are in general due to the steepness of the slopes to either side of the canal. Such an influence may indeed play its part. The controlling cause appears rather to be tilted underlying rock. The mass on the rock moves down however it may be piled up. It seems rather curious, though, that the canal should have been located just where two tilted rock surfaces intersect each other — that is, just above the bottom of a hidden rock valley.

ABOUT GLACIERS

By Élisée Reclus

EVEN in the midst of summer, when all the snow is melted by the breath of the warm winds, enormous accumulations of ice, imprisoned in the upper valleys, still produce a local winter, appearing all the more curious from the contrast. When the sun shines with all its brilliancy, both the direct heat and that sent forth by the glaciers are felt oppressively by the traveler; it even seems to be hotter than in the valleys, owing to the dryness of the air, incessantly deprived of its humidity by the glacier's greedy surface. Birds can be heard singing close by beneath the foliage; flowers stud the grass, fruit ripens under the whortleberry leaves. And yet, side by side with this joyous world, there lies the gloomy glacier, with its gaping crevices, its collection of stones, its terrible silence, its apparent immobility. It is death by the side of life.

Nevertheless, the great frozen mass possesses its motion also: slowly, but with an invincible force, it works as do the wind, snow, rain, running water, to renew the planet's surface. Wherever glaciers have passed over, during one of the ages of the earth's existence, the aspect of the country has been transformed by their action. As do avalanches, they carry the rubbish of the crumbling mountains into the plains, not by violence, but by the patient labor of every moment.

The work of the glacier, so difficult to discover in its secret progress, although so vast in its results, commences from the summit of the mountain, on the surface of the snowy strata. Up above in the amphitheaters where the clouds of white spicules, lashed by the storm, have been collected in whirlwinds, the uniform expanse of the snowbanks does not change its aspect. From year to year, from century to century, it is always the same whiteness, pale beneath the shadow of the clouds, dazzling beneath the rays of the sun. It appears as if the snow were eternal there, and it is thus designated by the inhabitants of the plains, who from below see it shining beside the heavens. They believe that it remains forever upon the lofty peaks, and that if the wind, during storms, does lift it up, it is always allowed to fall back into the same place.

It is nothing of the sort. One portion of the snow evaporates and returns to the clouds, whence it descended. Another portion, exposed to the rays of the sun, or to the influence of a hot southern wind, is sprinkled over with tiny melted drops, trickling down the surface or penetrating the strata until, seized upon again by the cold, they become congealed into imperceptible gems. Thus, by means of the millions of molecules which melt, then freeze to melt again, and again grow solid, the mass of snow becomes insensibly transformed; at the same time, owing to the weight which carries away the melted drops for several inches, it becomes displaced, and little by little the snow, so lately fallen upon the summit of the mountain, is found to have descended the slopes. Other snow has taken its place, and

will flow again in turn by a series of fusions, without, however, having to suffer the least apparent change. It is true that they have the infinitude of ages before them; slowly they move on towards the sea, where they must one day be swallowed up. By the time that two generations of men have succeeded one another in the lower plains, one of these flakes of snow, fallen from a lofty peak, will not yet have issued from the mass of the snow.

But, slow as it may be, this flake, converted into a crystal, does not the less hold on its course. The mass of snow, which has become homogeneous, and has already been transformed into ice, gets entangled in the mountain gorge, whither its weight draws it. Always immovable in appearance, the accumulation of ice has now become a real river flowing in a rocky bed. Upon the slopes to the right and left, the winter's snow is completely melted, and flowering plants have replaced it; a whole world of insects lives and buzzes amid the grass of the pastures; the air is soft, and man leads his flocks on to the grassy escarpments whence his glance can descend from afar upon the frozen stream. The latter, by unceasing efforts, continues its journey to the plain; it would stretch itself out as far as the level fields at the foot of the mountains — it would reach the sea itself — if the mild temperature of the lower valleys, the warmth of the winds, the rays of the sun, did not succeed in melting the foremost ice.

On its course, the solid river behaves as would a real one of running water. It has its meanderings, its eddies, its depths and shallows, its "torpids," its rapids,

and its cascades. Like the water, which expands or contracts according to the form of its bed, the ice adapts itself to the dimensions of the ravine containing it. It knows exactly how to mould itself upon the rock, as well in the vast basin whose walls widen out on either side as in the defile, where the passage almost closes up. Impelled by the masses, incessantly fed by the upper snow, the glacier continues to slide upon the bottom, the incline of which is almost insensible, or else forms a succession of precipices.

But the ice, not possessing the suppleness, the fluidity, of water, accomplishes, with a somewhat barbaric awkwardness, all the movements forced upon it by the nature of the ground. It cannot, at its cataracts, fall in one level sheet as does the water current; but, according to the inequalities of the bottom and the cohesion of the ice crystals, it fractures, splits, gets cut up into blocks inclining various ways, falling over one another, becoming cemented together again in curious obelisks, towers, fantastic groups. Even in that part where the bottom of the immense groove inclines with tolerable regularity, the surface of the glacier does not in the least resemble the even surface of the water of a river. The friction of the ice against its edges does not ripple it with tiny waves similar to those of the shore, but fractures and refractures it with crevices, intersecting one another in a labyrinth of fissures.

In winter, and even when spring has already renewed the ornamentation of the lower countries, a great number of crevasses are concealed beneath thick masses of snow, extending in continued layers along the surface

THE MUIR GLACIER IN THE SEVENTIES, SHOWING ICE CLIFFS AND STRANDED ICEBERGS

of the glacier; then, if the granulous snow has not been softened by the sun's heat, it is easy to walk above the mouth of these hidden abysses. The traveler can ignore them, as he ignores the open caves in the thickness of the mountains. But the annual return of the summer season by degrees melts the superficial snow. The glacier, moving on incessantly, and whose fractured mass vibrates in one continual tremor, shakes off the snowy mantle covering it; here and there the vaults fall in, and in great fragments bury themselves in the depths of the crevasses; frequently nothing remains but the narrow bridges upon which no person would venture without having tested the solidity of the snow with his foot.

It is then that it becomes dangerous to traverse many a glacier on account of the width of its fissures, branching out to infinity. From the edges of the chasm we sometimes see in the interior of the superimposed layers of bluish ice, which recently were snow and are separated by blackish bands, the remains of débris fallen upon the snow; at other times the ice, clear, homogenous in its whole mass, appears to be but one single crystal.

What is the depth of the well? We do not know. A jutting crag of ice, combined with the darkness, prevents our glance descending to the lowest rocks; yet we sometimes hear a mysterious noise ascending from the abyss: it is the water rippling, a stone becoming loosened, a bit of ice splitting off and falling down.

Explorers have descended these chasms to measure their density and to study the temperature and composition of the deep ice. Sometimes they have been able to

do it without any great risk, by penetrating laterally into the clefts, by the jutting rocks which serve as banks to the rivers of ice. Frequently, too, they have been obliged to be let down by means of ropes, as is the miner who penetrates to the bosom of the earth. But for one scientific discoverer who, taking all necessary precautions, thus explores the holes of the glaciers, how many unhappy shepherds have been engulfed and met their death in those chasms! Yet we know of mountaineers who, having fallen to the bottom of these crevasses, wounded, bleeding, lost in the darkness, have preserved their courage and the resolution to see daylight once more. There was one who followed the course of a sub-glacial stream, and thus made a veritable journey below the enormous vault of pieces of falling ice. After a similar excursion, there is nothing left for the man to do but to descend into the chasm of a crater to explore the subterranean reservoir of lava.

We are certainly bound to award great praise to the courageous savant who descends into the depths of the glacier to study its channels or grooves, its air-bubbles, its crystals; but how many things may we not contemplate on the surface, how many charming details are we not permitted to perceive, how many laws are not revealed to our eyes, if we know how to look!

Really, in this apparent chaos everything is regulated by laws. Why should a fissure always be produced in the frozen mass opposite one point of the steep bank? Why at a certain depth below should the crevasse, which has gradually become enlarged, again bring its edges nearer each other and the glacier be recemented? Why

should the surface regularly bulge out in one part to become fissured elsewhere? On seeing all these phenomena, which roughly reproduce the ripples, wavelets, and eddies on the smooth sheets of the water of a river, we better understand the unity which, under such an infinity of aspects, presides over everything in nature.

When, by long exploration, we have become familiar with the glacier, and we know how to account to ourselves for all the little changes which take place upon its surface, it is a delight, a joy, to roam about it on a fine summer's day. The heat of the sun has endowed it with voice and motion. Tiny veins of water, almost imperceptible at first, are formed here and there; these unite in sparkling streamlets which wind at the bottom of miniature river-beds, hollowed out by themselves, and then suddenly disappear in a fissure in the ice, giving forth a low plaint in a silvery voice. They swell or fall according to the variations of the temperature. Should a cloud pass before the sun and cool the atmosphere, they barely continue to flow; when the heat becomes greater, the superficial rivulets assume the pace of torrents; they sweep away with them sand and pebbles to be deposited in alluvions, or to form high banks and islands; then toward evening they calm down, and soon the cold of the night congeals them afresh.

Beneath the rays of heat temporarily animating the field of the glacier by melting the superficial layer, the little world of pebbles, fallen from the neighboring walls, also becomes agitated. A gravel slope, situated on the edge of a murmuring stream of water, subsides by partial downfalls and plunges into the fissures. Elsewhere,

black, broken stones are scattered over the glacier; they absorb and concentrate the heat, making holes in the ice beneath them, piercing it with little cylindrical apertures. Farther off, on the contrary, vast accumulations of débris and big stones prevent the heat of the sun penetrating below; on every side the ice melts and evaporates. In the end these stones form pillars which appear to grow, to spring out of the ground like columns of marble; but each one, too weak, at last breaks beneath the weight, and all the fragments that it bore fall down with a crash, to recommence a similar evolution on the morrow. How much more charming are all these little dramas of inanimate nature when animals or plants take part in them! Attracted by the mildness of the air, the butterfly flutters on the scene, while the plant which fell down from the heights of the neighboring rocks in a landslip utilizes its short reprieve of life to take root again, and to display to the sun its last corolla. Navigators on the polar coast have seen a whole carpet of vegetation cover a high cliff composed of earth at the top and ice at the base.

THE BIRTH OF AN ICEBERG

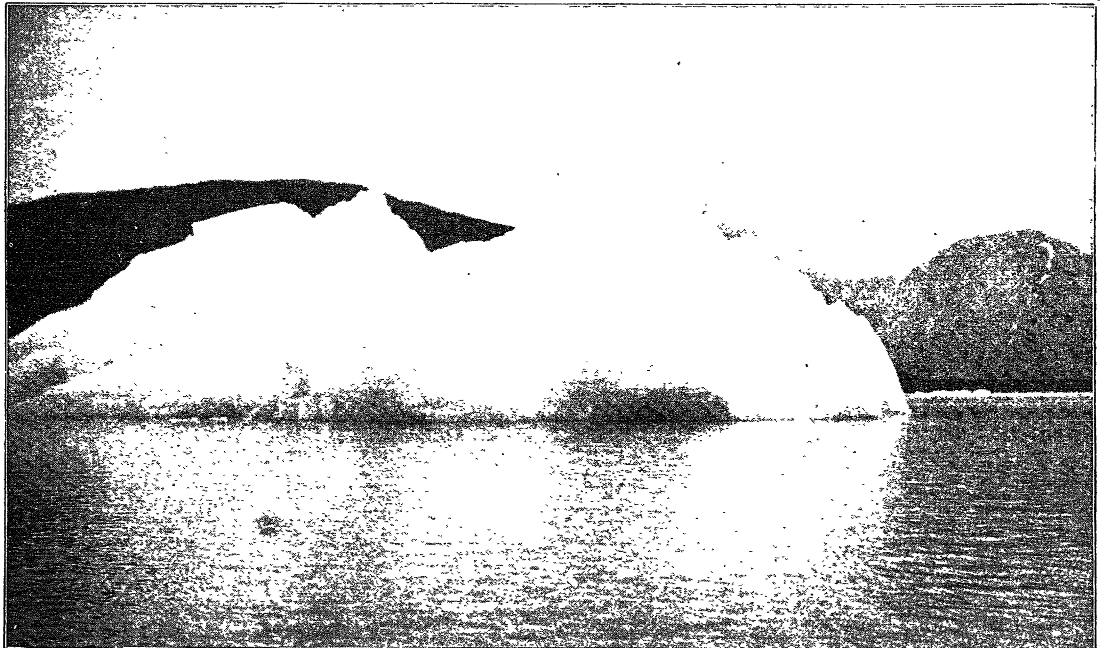
By John Muir

WHEN night was approaching, I scrambled down to the glacier, and returned to my lonely camp, and, getting some coffee and bread, again went up the moraine to the east end of the great ice-wall. It is about three miles long, but the length of the jagged, berg-producing portion that stretches across the fiord from side to side like a huge green-and-blue barrier is only about two miles and rises above the water to a height of from two hundred and fifty to three hundred feet. Soundings made by Captain Carroll show that seven hundred and twenty feet of the wall is below the surface, and a third unmeasured portion is buried beneath the moraine detritus deposited at the foot of it. Therefore, were the water and rocky detritus cleared away, a sheer precipice of ice would be presented nearly two miles long and more than a thousand feet high. Seen from a distance, as you come up the fiord, it seems comparatively regular in form, but it is far otherwise; bold, jagged capes jut forward into the fiord, alternating with deep, reëntering angles and craggy hollows with plain bastions, while the top is roughened with innumerable spires and pyramids and sharp hacked blades leaning and toppling or cutting straight into the sky.

The number of bergs given off varies somewhat with the weather and the tides, the average being about one

every five minutes, counting only those that roar loud enough to make themselves heard at a distance of two or three miles. The very largest, however, may under favorable conditions be heard ten miles or even farther. When a large mass sinks from the upper fissured portion of the wall, there is first a keen, prolonged, thundering roar, which slowly subsides into a low muttering growl, followed by numerous smaller grating, clashing sounds from the agitated bergs that dance in the waves about the newcomer as if in welcome; and these again are followed by the swash and roar of the waves that are raised and hurled up the beach against the moraines. But the largest and most beautiful of the bergs, instead of thus falling from the upper weathered portion of the wall, rise from the submerged portion with a still grander commotion, springing with tremendous voice and gestures nearly to the top of the wall, tons of water streaming like hair down their sides, plunging and rising again and again before they finally settle in perfect poise, free at last, after having formed part of the slow-crawling glacier for centuries. And as we contemplate their history, as they sail calmly away down the fiord to the sea, how wonderful it seems that ice formed from pressed snow on the far-off mountains two or three hundred years ago should still be pure and lovely in color after all its travel and toil in the rough mountain quarries, grinding and fashioning the features of predestined landscapes.

When sunshine is sifting through the midst of the multitude of icebergs that fill the fiord and through the jets of radiant spray ever rising from the tremendous



FLOATING ICEBERG, TAKU INLET, ALASKA

dashing and splashing of the falling and upspringing bergs, the effect is indescribably glorious. Glorious, too, are the shows they make in the night when the moon and stars are shining. The berg-thunder seems far louder than by day, and the projecting buttresses seem higher as they stand forward in the pale light, relieved by gloomy hollows, while the new-born bergs are dimly seen, crowned with faint lunar rainbows in the up-dashing spray. But it is in the darkest nights when storms are blowing and the waves are phosphorescent that the most impressive displays are made. Then the long range of ice-bluffs is plainly seen stretching through the gloom in weird, unearthly splendor, luminous wave foam dashing against every bluff and drifting berg; and ever and anon amid all this wild auroral splendor some huge new-born berg dashes the living water into yet brighter foam, and the streaming torrents pouring from its sides are worn as robes of light, while they roar in awful accord with the winds and waves, deep calling unto deep, glacier to glacier, from fiord to fiord over all the wonderful bay.

THE LIFE-HISTORY OF A LAKE

By John Muir

WHEN a mountain lake is born, — when, like a young eye, it first opens to the light, — it is an irregular, expressionless crescent, inclosed in banks of rock and ice, — bare, glaciated rock on the lower side, the rugged snout of a glacier on the upper. In this condition it remains for many a year, until at length, toward the end of some auspicious cluster of seasons, the glacier recedes beyond the upper margin of the basin, leaving it open from shore to shore for the first time, thousands of years after its conception beneath the glacier that excavated its basin. The landscape, cold and bare, is reflected in its pure depths; the winds ruffle its glassy surface, and the sun fills it with throbbing spangles, while its waves begin to lap and murmur around its leafless shores, — sun-spangles during the day and reflected stars at night its only flowers, the winds and the snow its only visitors. Meanwhile, the glacier continues to recede, and numerous rills, still younger than the lake itself, bring down glacier-mud, sand-grains, and pebbles, giving rise to margin-rings and plats of soil. To these fresh soil-beds come many a waiting plant. First, a hardy carex with arching leaves and a spike of brown flowers; then, as the seasons grow warmer, and the soil-beds deeper and wider, other sedges take their appointed places, and these

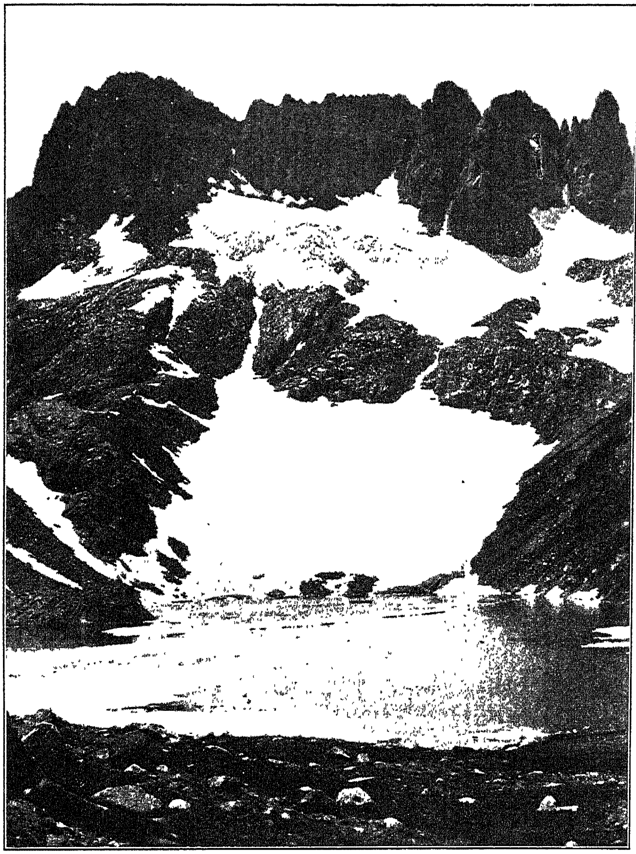
are joined by blue gentians, daisies, dodecatheons, violets, honeyworts, and many a lowly moss. Shrubs also hasten in time to the new gardens, — kalmia with its glossy leaves and purple flowers, the arctic willow, making soft woven carpets, together with the heathy bryanthus and cassiope, the fairest and dearest of them all. Insects now enrich the air, frogs pipe cheerily in the shallows, soon followed by the ouzel, which is the first bird to visit a glacier lake, as the sedge is the first of plants.

So the young lake grows in beauty, becoming more and more humanly lovable from century to century. Groves of aspen spring up, and hardy pines, and the Hemlock Spruce, until it is richly overshadowed and embowered. But while its shores are being enriched, the soil-beds creep out with incessant growth, contracting its area, while the lighter mud-particles deposited on the bottom cause it to grow constantly shallower, until at length the last remnant of the lake vanishes, — closed forever in ripe and natural old age. And now its feeding-stream goes winding on without halting through the new gardens and groves that have taken its place.

The length of the life of any lake depends ordinarily upon the capacity of its basin, as compared with the carrying power of the streams that flow into it, the character of the rocks over which these streams flow, and the relative position of the lake toward other lakes. In a series whose basins lie in the same cañon, and are fed by one and the same main stream, the uppermost will, of course, vanish first unless some other lake-filling agent comes in to modify the result; because at first it receives nearly

all of the sediments that the stream brings down, only the finest of the mud-particles being carried through the highest of the series to the next below. Then the next higher and the next would be successively filled, and the lowest would be the last to vanish. But this simplicity as to duration is broken in upon in various ways, chiefly through the action of side-streams that enter the lower lakes direct. For, notwithstanding many of these side tributaries are quite short, and, during late summer, feeble, they all become powerful torrents in springtime when the snow is melting, and carry not only sand and pine-needles, but large trunks and boulders tons in weight, sweeping them down their steeply inclined channels and into the lake basins with astounding energy. Many of these side affluents also have the advantage of access to the main lateral moraines of the vanished glacier that occupied the cañon, and upon these they draw for lake-filling material, while the main trunk stream flows mostly over clean glacier pavements, where but little moraine matter is ever left for them to carry. Thus a small rapid stream with abundance of loose transportable material within its reach may fill up an extensive basin in a few centuries, while a large perennial trunk stream, flowing over clean, enduring pavements, though ordinarily a hundred times larger, may not fill a smaller basin in thousands of years.

The comparative influence of great and small streams as lake-fillers is strikingly illustrated in Yosemite Valley, through which the Merced flows. The bottom of the valley is now composed of level meadow-lands and dry, sloping soil-beds planted with oak and pine, but it was



A GLACIER LAKE

once a lake stretching from wall to wall and nearly from one end of the valley to the other, forming one of the most beautiful cliff-bound sheets of water that ever existed in the Sierra. And though never perhaps seen by human eye, it was but yesterday, geologically speaking, since it disappeared, and the traces of its existence are still so fresh, it may easily be restored to the eye of imagination and viewed in all its grandeur, about as truly and vividly as if actually before us. Now we find that the detritus which fills this magnificent basin was not brought down from the distant mountains by the main streams that converge here to form the river, however powerful and available for the purpose at first sight they appear; but almost wholly by the small local tributaries, such as those of Indian Cañon, the Sentinel, and the Three Brothers, and by a few small residual glaciers which lingered in the shadows of the walls long after the main trunk glacier had receded beyond the head of the valley.

Had the glaciers that once covered the range been melted at once, leaving the entire surface bare from top to bottom simultaneously, then of course all the lakes would have come into existence at the same time, and the highest, other circumstances being equal, would, as we have seen, be the first to vanish. But because they melted gradually from the foot of the range upward, the lower lakes were the first to see the light and the first to be obliterated. Therefore, instead of finding the lakes of the present day at the foot of the range, we find them at the top. Most of the lower lakes vanished thousands of years before those now brightening the alpine land-

scapes were born. And in general, owing to the deliberation of the upward retreat of the glaciers, the lowest of the existing lakes are also the oldest, a gradual transition being apparent throughout the entire belt, from the older, forested, meadow-rimmed and contracted forms all the way up to those that are new born, lying bare and meadowless among the highest peaks.

A few small lakes unfortunately situated are extinguished suddenly by a single swoop of an avalanche, carrying down immense numbers of trees, together with the soil they were growing upon. Others are obliterated by land-slips, earthquake taluses, etc., but these lake-deaths, compared with those resulting from the deliberate and incessant deposition of sediments, may be termed accidental. Their fate is like that of trees struck by lightning.

HOW A VOLCANO PAINTED THE SKY

By Sir Robert Stawell Ball

UNTIL the year 1883 few had ever heard of Krakatoa. It was unknown to fame, as are hundreds of other gems of glorious vegetation set in tropical waters. It was not inhabited, but the natives from the surrounding shores of Sumatra and Java used occasionally to draw their canoes up on its beach, while they roamed through the jungle in search of the wild fruits that there abounded. Geographers in early days hardly condescended to notice Krakatoa; the name of the island on their maps would have been far longer than the island itself. It was known to the mariner who navigated the Straits of Sunda, for it was marked on his charts as one of the perils of the intricate navigation in those waters. It was no doubt recorded that the locality had once been, or more than once, the seat of an active volcano. In fact, the island seemed to owe its existence to some frightful eruption of bygone days; but for a couple of centuries there had been no fresh outbreak. It almost seemed as if Krakatoa might be regarded as a volcano that had become extinct. In this respect it would only be like many other similar objects all over the globe, or like the countless extinct volcanoes all over the moon.

In 1883 Krakatoa suddenly sprang into notoriety. Insignificant though it had hitherto seemed, the little

island was soon to compel by its tones of thunder the whole world to pay it instant attention. It was to become the scene of a volcanic outbreak so appalling that it is destined to be remembered throughout the ages. In the spring of that year there were symptoms that the volcanic powers in Krakatoa were once more about to awake from the slumber that had endured for many generations. Notable warnings were given. Earthquakes were felt, and deep rumblings proceeded from the earth, showing that some disturbance was in preparation, and that the old volcano was again to burst forth after its long period of rest. At first the eruption did not threaten to be of any serious type; in fact, the good people of Batavia, so far from being terrified at what was in progress at Krakatoa, thought the display was such an attraction that they chartered a steamer and went forth for a pleasant picnic to the island. Many of us, I am sure, would have been delighted to be able to join the party who were to witness so interesting a spectacle. With cautious steps the more venturesome of the excursion party clambered up the sides of the volcano, guided by the sounds which were issuing from its summit. There they beheld a vast column of steam pouring forth with terrific noise from a profound opening about thirty yards in width.

As the summer of this dread year advanced the vigor of Krakatoa steadily increased, the noises became more and more vehement; these were presently audible on shores ten miles distant, and then twenty miles distant; and still these noises waxed louder and louder, until the great thunders of the volcano, now so rapidly develop-

ing, astonished the inhabitants that dwelt over an area at least as large as Great Britain. And there were other symptoms of the approaching catastrophe. With each successive convulsion a quantity of fine dust was projected aloft into the clouds. The wind could not carry this dust away as rapidly as it was hurled upwards by Krakatoa, and accordingly the atmosphere became heavily charged with suspended particles. A pall of darkness thus hung over the adjoining seas and islands. Such was the thickness and the density of these atmospheric volumes of Krakatoa dust that, for a hundred miles around, the darkness of midnight prevailed at midday. Then the awful tragedy of Krakatoa took place. Many thousands of the unfortunate inhabitants of the adjacent shores of Sumatra and Java were destined never to behold the sun again. They were presently swept away to destruction in an invasion of the shore by the tremendous waves with which the seas surrounding Krakatoa were agitated.

Gradually the development of the volcanic energy proceeded, and gradually the terror of the inhabitants of the surrounding coasts rose to a climax. July had ended before the manifestations of Krakatoa had attained their full violence. As the days of August passed by, the spasms of Krakatoa waxed more and more vehement. By the middle of that month the panic was widespread, for the supreme catastrophe was at hand.

On the night of Sunday, August 26, 1883, the blackness of the dust clouds, now much thicker than ever in the Straits of Sunda and adjacent parts of Sumatra and Java, was only occasionally illumined by lurid flashes

from the volcano. The Krakatoan thunders were on the point of attaining their complete development. At the town of Batavia, a hundred miles distant, there was no quiet that night. The houses trembled with the subterranean violence, and the windows rattled as if heavy artillery were being discharged in the streets. And still these efforts seemed to be only rehearsing for the supreme display. By ten o'clock in the morning of Monday, August 27, 1883, the rehearsals were over and the performance began. An overture, consisting of two or three introductory explosions, was succeeded by a frightful convulsion which tore away a large part of the island of Krakatoa and scattered it to the winds of heaven. In that final effort all records of previous explosions on this earth were completely broken.

This supreme effort it was which produced the mightiest noise that, so far as we can ascertain, has ever been heard on this globe. It must have been indeed a loud noise which could travel from Krakatoa to Batavia and preserve its vehemence over so great a distance; but we should form a very inadequate conception of the energy of the eruption of Krakatoa if we thought that its sounds were heard by those merely a hundred miles off. This would be little, indeed, compared with what is recorded, on testimony which it is impossible to doubt.

Westward from Krakatoa stretches the wide expanse of the Indian Ocean. On the opposite side from the Straits of Sunda lies the island of Rodriguez, the distance from Krakatoa being almost three thousand miles. It has been proved by evidence which cannot be doubted

that the thunders of the great volcano attracted the attention of an intelligent coastguard on Rodriguez, who carefully noted the character of the sounds and the time of their occurrence. He had heard them just four hours after the actual explosion, for this is the time the sound occupied on its journey.

Let us suppose that a similar earth-shaking event took place in a central position in the United States. Let us say, for example, that an explosion occurred at Pike's Peak as resonant as that from Krakatoa. It would certainly startle not a little the inhabitants of Colorado far and wide. The ears of dwellers in the neighboring States would receive a considerable shock. With lessening intensity the sound would spread much farther around — indeed, it might be heard all over the United States. The sonorous waves would roll over to the Atlantic coast, they would be heard on the shores of the Pacific. Florida would not be too far to the south, nor Alaska too remote to the north. If, indeed, we could believe that the sound would travel as freely over the great continent as it did across the Indian Ocean, then we may boldly assert that every ear in North America might listen to the thunder from Pike's Peak, if it rivaled Krakatoa. The reverberation might even be audible to skin-clad Eskimos amid the snows of Greenland, and to naked Indians sweltering on the Orinoco. Can we doubt that Krakatoa made the greatest noise that has ever been recorded?

Among the many other incidents connected with this explosion, I may specially mention the wonderful system of divergent ripples that started in our atmosphere

from the point at which the eruption took place. I have called them ripples, from the obvious resemblance which they bear to the circular expanding ripples produced by raindrops which fall upon the still surface of water. But it would be more correct to say that these objects were a series of great undulations which started from Krakatoa and spread forth in ever-enlarging circles through our atmosphere. The initial impetus was so tremendous that these waves spread for hundreds and thousands of miles. They diverged in fact, until they put a mighty girdle round the earth, on a great circle of which Krakatoa was the pole. The atmospheric waves, with the whole earth now well in their grasp, advanced into the opposite hemisphere. In their further progress they had necessarily to form gradually contracting circles, until at last they converged to a point in Central America, at the very opposite point of the diameter of our earth, eight thousand miles from Krakatoa. Thus the waves completely embraced the earth. Every part of our atmosphere had been set into a tingle by the great eruption. In Great Britain the waves passed over our heads, the air in our streets, the air in our houses, trembled from the volcanic impulse. The very oxygen supplying our lungs was responding also to the supreme convulsion which took place ten thousand miles away. It is needless to object that this could not have taken place because we did not feel it. Self-registering barometers have enabled these waves to be followed unmistakably all over the globe.

Such was the energy with which these vibrations were initiated at Krakatoa, that even when the waves thus

arising had converged to the point diametrically opposite in South America their vigor was not yet exhausted. The waves were then, strange to say, reflected back from their point of convergence to retrace their steps to Krakatoa. Starting from Central America, they again described a series of enlarging circles, until they embraced the whole earth. Then, advancing into the opposite hemisphere, they gradually contracted until they had regained the Straits of Sunda, from which they had set forth about thirty-six hours previously. Here was, indeed, a unique experience. The air waves had twice gone from end to end of this globe of ours. Even then the atmosphere did not subside until, after some more oscillations of gradually fading intensity, at last they became evanescent.

But, besides these phenomenal undulations, this mighty incident at Krakatoa has taught us other lessons on the constitution of our atmosphere. We previously knew little, or I might say, nothing, as to the conditions prevailing above the height of ten miles overhead. We were almost altogether ignorant of what the wind might be at an altitude of, let us say, twenty miles. It was Krakatoa which first gave us a little information which was greatly wanted. How could we learn what winds were blowing at a height four times as great as the loftiest mountain on the earth, and twice as great as the loftiest altitude to which a balloon had ever soared? We could neither see these winds nor feel them. How, then, could we learn whether they really existed? No doubt a straw will show the way the winds blow, but there are no straws up there. There was nothing to

render the winds perceptible until Krakatoa came to our aid. Krakatoa drove into those winds prodigious quantities of dust. Hundreds of cubic miles of air were thus deprived of that invisibility which they had hitherto maintained. They were thus compelled to disclose those movements about which, neither before nor since, have we had any opportunity of learning.

With eyes full of astonishment men watched those vast volumes of Krakatoa dust start on a tremendous journey. Westward the dust of Krakatoa took its way. Of course every one knows the so called tradewinds on our earth's surface, which blow steadily in fixed directions, and which are of such service to the mariner. But there is yet another constant wind. We cannot call it a tradewind, for it never has rendered any service to navigation. It was first disclosed by Krakatoa. Before the occurrence of that eruption no one had the slightest suspicion that far up aloft, twenty miles over our heads, a mighty tempest is incessantly hurrying with a speed much greater than that of the awful hurricane which once laid so large a part of Calcutta on the ground, and slew so many of its inhabitants. Fortunately for humanity, this new tradewind does not come within less than twenty miles of the earth's surface. We are thus preserved from the fearful destruction that its unintermittent blasts would produce, blasts against which no tree could stand, and which would in ten minutes do as much damage to a city as would the most violent earthquake. When this great wind had become charged with the dust of Krakatoa, then, for the first

time, it stood revealed to human vision. Then it was seen that this wind circled round the earth in the vicinity of the Equator, and completed its circuit in about thirteen days.

Please observe the contrast between this wind of which we are now speaking and the waves to which we have just referred. The waves were merely undulations or vibrations produced by the blow which our atmosphere received from the explosion of Krakatoa, and these waves were propagated through the atmosphere much in the same way as sound waves are propagated. Indeed, these waves moved with the same velocity as sound. But the current of air of which we are now speaking was not produced by Krakatoa; it existed from all time, before Krakatoa was ever heard of, and it exists at the present moment, and will doubtless exist as long as the earth's meteorological arrangements remain as they are at present. All that Krakatoa did was simply to provide the charges of dust by which for one brief period this wind was made visible.

In the autumn of 1883 the newspapers were full of accounts of strange appearances in the heavens. The letters containing these accounts poured in upon us from residents in Ceylon; they came from residents in the West Indies, and from other tropical places. All had the same tale to tell. Sometimes experienced observers assured us that the sun looked blue; sometimes we were told of the amazement with which people beheld the moon draped in vivid green. Other accounts told of curious halos, and, in short, of the signs in the sun, the moon, and the stars, which were exceedingly unusual,

even if we do not say that they were absolutely unprecedented.

Those who wrote to tell of the strange hues that the sun manifested to travelers in Ceylon, or to planters in Jamaica, never dreamed of attributing the phenomena to Krakatoa, many thousands of miles away. In fact, these observers knew nothing at the time of the Krakatoa eruption, and probably few of them, if any, had ever heard that such a place existed. It was only gradually that the belief grew that these phenomena were due to Krakatoa. But when the accounts were carefully compared, and when the dates were studied at which the phenomena were witnessed in the various localities, it was demonstrated that these phenomena, notwithstanding their worldwide distribution, had certainly arisen from the eruption in this little island in the Straits of Sunda. It was most assuredly Krakatoa that painted the sun and the moon, and produced the other strange and weird phenomena in the tropics.

It was in the late autumn of 1883 that the marvelous series of celestial phenomena connected with the great eruption began to be displayed in Great Britain. Then it was that the glory of the ordinary sunsets was enhanced by a splendor which had dwelt in the memory of all those who were permitted to see them. There is not the least doubt that it was the dust from Krakatoa which produced the beauty of these sunsets, and so long as that dust remained suspended in our atmosphere, so long were strange signs to be witnessed in the heavenly bodies. But the dust which had been borne with unparalleled violence from the interior of the volcano, the

dust which had been shot aloft by the vehemence of the eruption to an altitude of twenty miles, the dust which had thus been whirled round and round our earth for perhaps a dozen times or more in this air current, which carried it round in less than a fortnight, was endowed with no power to resist forever the law of gravitation which bids it fall to the earth. It therefore gradually sank downwards. Owing, however, to the great height to which it had been driven, owing to the impetuous nature of the current by which it was hurried along, and owing to the exceedingly minute particles of which it was composed, the act of sinking was greatly protracted. Not until two years after the original explosion had all the particles with which the air was charged by the great eruption finally subsided on the earth.

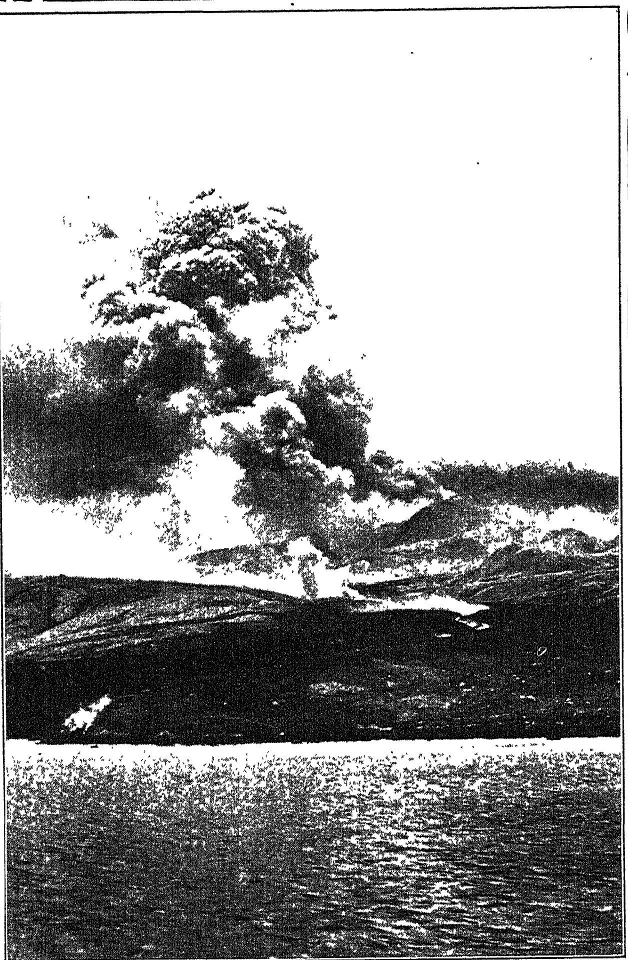
At first there were some who refused to believe that the glory of the sunsets in London could possibly be due to a volcano in the Straits of Sunda, at a distance from England which was but little short of that of Australia. But the gorgeous phenomena in England were found to be simultaneous with similar phenomena in other places all round the earth. Once again the comparison of dates and other circumstances proved that Krakatoa was the cause of these exceptional and most interesting phenomena. Tennyson, ever true to nature, records the event in immortal verse —

> "Had the fierce ashes of some fiery peak
> Been hurled so high they ranged around the world,
> For day by day through many a blood-red eve
> The wrathful sunset glared."

BATTLING WITH MONT PELÉE

By Angelo Heilprin

OUR course up Pelée was from this point the same that I had taken on my previous ascents, over the easy arête that forms the central eastern ray of the volcano, and lies a little northward of the ravine of the Falaise. The conditions of the ascent on this day were surprisingly favorable, and we were able to make use of our animals up to a height of nearly two thousand three hundred feet. A light growth of grass had begun to cover the arid slope of ash and cinder, and the blackened forest of the ravine slopes was also touched on the crown with green. The beautiful tree-ferns, more particularly, gave evidence of this new life, and they promised to restore in a short time to Mont Pelée that verdure for which the mountain had been dear to the Martiniquians. It was evident that the burned forest was not absolutely dead, and its greens were already being picked by troops of blackbirds, fly-catchers, and the *hirondelle-mouche*. Myriads of green and green and black caterpillars were cropping the new vegetation. They had found a comfortable home in this newly regenerated upper world, and were making the best of their time. It was evident that the volcano had blown to them a good wind. Such sudden visitations of insects to recovering volcanic regions have been noted before, and have brought



MONT PELÉE IN ERUPTION

many problems to the entomologist which still await solution.

We left our animals shortly after eight o'clock, and at that time the volcano was raging. The steam-cloud roared out of a seething furnace and swept the summit from our view. Back of us dark-blue shadows were checkering the receding landscape, but the ocean was the blue and green of the coral reef, and lovely Morne Rouge was bathed in warm sunshine. Nearer to us Ajoupa-Bouillon, slumbering in sunlight and shadow, lay almost at our feet. We picked our way leisurely up the cinder slope, but it was evident that ejected bombs had recently scarred its surface, for there were furrows and troughs and great boulders where none had been before. We also noted a number of puzzling crater-like shallow pits or hollows which some have thought to associate with falling rocks, others with earthquake phenomena. In a few minutes more we were in the storm-cloud, with only bits of landscape to follow us as companions. The great knob of Morne Jacob appeared and disappeared, and at intervals we could glance into the deep gorges on either side of us, but of the summit of the mountain there was nothing. Our Martinique associates were uneasy, for from the invisible gray ahead came the terrific voice of the volcano. There were no accentuated detonations, but a continuous roar that was simply appalling. I thought on my previous ascent to have heard something, but this time it was the old sound multiplied a hundred-fold. No words can describe it. Were it possible to unite all the furnaces of the globe into a single one, and to simultaneously let loose their blasts of

steam, it does not seem to me that such a sound could be produced. It was not loud in the sense of a peal of thunder, but of fiery and tempestuous storm, that could best be compared with the blowing of the ocean's wind through the shrouds of a full-rigged ship, only ten times that. The mountain fairly quivered under its work, and it was perhaps not wholly discreditable that some of us should have felt anything but comfortable.

Where was all this? we asked ourselves. In front of us, but invisible. My aneroid gave for our elevation three thousand four hundred feet, — therefore we were only six hundred feet below the summit-level which marked the position of the Lac des Palmistes. There appeared to be no barometric disturbance, nor was the compass-needle affected. A whistling bomb flew past us at this time, but it left but a comet's train in our ears, for it could not be seen. We took it first for a flying bird, but its course was soon followed by another, and then came the dull thud of its explosion in air. Deep down the river we could hear the scattered parts tumbling, sliding, and crackling. We could no longer deceive ourselves as to the character of the struggle into which we had entered. The ominous clicks in the air told us what to expect.

We moved up slowly, hardly more than a few paces at a time, but with hope given to us in the occasional rifting of the clouds. Time and time again the summit crest appeared beneath the rolling vapors, and it really seemed as if the cone, of which we were in search, would suddenly come to view. When we had reached about three thousand eight hundred feet the fusillade of bombs became overpoweringly strong, and we were obliged to

retreat. We were in battle. The clouds had become lighter, and we could at times see the bombs and boulders coursing through the air in parabolic curves and straight lines, driven and shot out as if from a giant catapult. They whistled past us on both sides and our position became decidedly uncomfortable; many of the fragments took almost direct paths, and must have been shot into their courses as a result of explosions taking place above the summit of the volcano. They flew by us at close range. Descending perhaps one hundred feet lower on the slope, we took shelter under a somewhat rolling knob and waited for a possible cessation of the fusillade. A glance at my men showed that they were thoroughly frightened, and most of them were making quick tracks to a lower level. A lull favored a further effort. Not wishing to incur any responsibility in a call for company in what appeared to be a rather hazardous enterprise, I made a second attempt by myself, keeping my body as close to the ground as was possible. The clouds soon separated me from my associates, and all of visible nature that was left to me was a patch of slope and the shifting vapors. Mr. Cochrane's figure was the last to disappear. The roar of the volcano was terrific — awful beyond description. It felt as if the very earth were being sawed in two. In about a quarter of an hour I reached a point just below the summit — the crest of the old lake basin — which was being raked heavily by the fire of the volcano. I could see no more than before. Everything was as if in a surging sea, and neither the cone nor what was left of the Morne de La Croix was visible. It was useless to remain longer in the open fire,

and I descended to join my associates. Mr. Cochrane was near at hand, working his camera and seemingly indifferent to the encircling storm, but the negroes had gone far below, carrying our provisions with them. I was surprised, indeed, that they should have retained their courage for so long a time, for Pelée had been unusually active for a number of days, and if men ever feared anything, it was this grim monster of Martinique. But most of them had remembered my earlier ascents, and they childishly seemed to feel that there was shelter in my wake.

Shortly before noon a sudden lifting of the clouds revealed the volcano in all its majestic fury. For the first time since we reached its slopes were we permitted to see its steam-column — that furious, swirling mass ahead of us, towering miles above the summit, and sweeping up in curls and festoons of white, yellow, and almost black. It boiled with ash. The majestic cauliflower clouds rose on all sides, joining with the central column, and it was evident that the entire crater was working, bottom as well as summit, and with a vigor that it would be useless to attempt to describe. Higher and higher they mount, until the whole is lost in the great leaden umbrella which seemed to overspread the whole earth. I estimated the diameter of the column as it left the crest of the mountain to be not less than fifteen hundred feet, and its rate of ascent from one and a half to two miles a minute, and considerably greater at the initial moment of every new eruption. Great exploding puffs were following one another in rapid succession, and they told the story of what was going on inside the volcano.

Cochrane and I were not the only ones to be inspired by this extraordinary and bewildering spectacle. Our Martinique men seemed equally overcome by a grandeur of nature, terrifying as it was beautiful, which they had not before seen, and of their own accord initiated a new effort to reach the summit. We climbed back to our former position, but the bombardment was too strong for us, and we thought best to desist. The prospects for study were anything but promising, and it was thought unnecessary at this time to take further risks. Of our party of twelve there were now only four left on the upper slopes of the volcano, but we still hoped for one more chance. For a half hour or so we took refuge in a hollow sufficiently deep to about clear our heads, and waited. But even the pleasures of a mountain lunch did not quite make this place restful, for the bursting bombs flew thick to one side, and we were too eager to watch the flying fragments to permit ourselves a free moment. Every scattering mass brought us to our feet, only to see and hear the fragments plunging into the abyss that lay to one side. Cochrane and I moved a piece higher up, and then abandoned the effort. "Where did this last block burst?" I asked of my associate, and before my question was answered, we were spattered with mud from head to foot by a great boulder, hardly smaller than a flour barrel, which fell within ten feet of us, or less.

When we reached the lower slopes, we were covered with ash and mud. For an hour or more we were nearly beneath the center of the great ash-cloud, whose murky masses hung at a dizzy height above us. Its mantle-

sheet carried darkness to Macouba and Grande Rivière, and far over Dominica and Guadeloupe the black mass still swept out to sea. I believe that the ash-cloud must have been fully six miles above our heads. It rolled out a few peals of thunder, but we observed no flashes of lightning. The ash fell lightly, and coming mixed with water soon consolidated into a paste. It had the temperature of the surrounding air — was not warm. There were no large particles. The coarser material fell miles from us, at positions situated more nearly under the periphery of the cloud.

It is singular that even at the point where I was nearest to the issuing steam, a distance of probably less than four hundred feet, no marked atmospheric disturbance was perceptible, nothing to even remotely suggest a cyclonic or suctional whirl. One could readily have expected something of this kind to occur. Nor do I believe that there was any noticeable elevation in the temperature of the air. Unfortunately, the single thermometer that I had with me had broken earlier in the day, and, therefore, my note on this point rests solely on a personal impression. Certainly there was no emphasized change in temperature. I could detect no gaseous emanations, except, perhaps, a very feeble taint of sulphur.

When we again got on the level ground back of the Habitation Leyritz we were startled by a most violent eruption from Pelée, a great shaft of steam and ash being suddenly shot out to a most marvelous height, perhaps not less than five or six miles. It went up as a distinct column of its own, swiftly distancing the other cloud-

masses by which it was enveloped. It was a prelude to the incidents of the evening that followed.

We arrived at our shelter a little before five o'clock, somewhat to the relief of the household, who had become apprehensive regarding our safety. While still seated at the table, a flash of lightning and a dull thud told us in an instant that something was happening. We were out at once. This was a few minutes, perhaps a quarter of an hour, after nine o'clock. The volcano was still distantly growling. The heavens were aglow with fire, electric flashes of blinding intensity traversing the recesses of black and purple clouds, and casting a lurid pallor over the darkness that shrouded the world. Scintillating stars burst forth like crackling fireworks, and serpent lines wound themselves in and out like traveling wave-crests. The spectacle was an extraordinary and terrifying one, and I confess that it left an impression of uncomfortable doubt in our minds as to what would be the issue. One could not but feel that tremendous destruction was impending.

The number of forms in which the illumination appeared was bewildering, and I can only recall a few the picture of which presented itself to my eyes with precision; short, straight, rod-like lines, wave-lines, spirals, long-armed stars, and circles with star-arms hanging off from the border like so many tails. In addition to these were the scintillant stars to which reference has already been made, and the blinding flashes of normal or zig zag lightning. There were no peals of thunder, but a continuous roar swept through the heavens, mounting with crescendos and falling off with alternating, far-

reaching diminuendos. Some pretend to have heard a feeble crackling, like that which is so often heard in association with an auroral display, but I am not sure that I could record this condition, which may easily have existed, among my own experiences. The flashes were bewilderingly numerous, and the singular forms interwoven with one another in such a way as to make a localization difficult. The scintillant stars alone appeared to have a place of their own, nearer the border of the great cloud, and perhaps in the highest parts of it. Directly over the summit of Pelée there was little to be seen. Who is there to tell us what these peculiar flashes are? Are they electric, or are they the flashes of burning gases? It would probably be easy to determine their nature by means of the spectroscope, but this form of examination has not yet been made. It is certain that most of them are not connective discharges, for they run through, or are contained in, individual clouds of small dimensions. The phenomena appear to be identical with those which were noted to accompany the great eruption of Tarawera, in New Zealand, in 1886.

As our eyes feasted upon this scene of majestic grandeur, we almost lost sight of the fact that ashes were falling about us. A great pattering of pumice and lapilli had ushered in the storm, and for a while it sounded as if we were in a tropical hail-storm. Only the fragments first thrown were large, a few an inch or more in size, and those following were like peas and lentils, and then like sand. But even the smaller particles came down with much force, and the flesh stung as it was touched by them. They were all angular bits of andesite or trachyte,

white and gray in color. We were out in our bared heads, but it was soon found necessary to protect them. The fall lasted somewhat over an hour, or to nearly half-past ten. All motion in the atmosphere ceased at this time, and for once the location Leyritz lost its usual refreshing coolness. The falling ash felt warm, but M. des Grottes's thermometer failed to indicate anything special.

It was not given to us to close the night quietly. The flashing sky above and the falling ash had yet a complement. For over an hour the southwest was glowing fiery red, and patches of lurid light moved themselves into the black of the volcanic cloud. No flame was visible, but it was only too evident that fire was devastating somewhere. Morne Rouge lay to the same point of the compass, and we intuitively asked ourselves if it could be that town aflame. When we retired for the night, M. des Grottes had decided to desert the habitation. Pelée was too close to us, and too active to be sought for as the simple ornament which it had been designated by the Scientific Commission of 1851. Most of the working inhabitants of the plantation had betaken themselves to the coast immediately after the first storm of the evening, terror-stricken with the unceasing roar of the volcano and the flashing lightning, and my own men had joined them in their mad flight. All thoughts of a new exploration of the summit of the volcano on the morrow had vanished. It was not without apprehension that the great door of the manse was closed that night. I did not quite share M. des Grottes's fears that there might be no one in the morning to open it, but the hours for rest were spent mainly in thinking.

The night-air was almost without breeze, so different from what we had had up till now. I tossed around until about one o'clock, sleeping in snatches, but hardly resting. At this time there was another sharp pattering of cinders, and I moved up to the window, only to see darkness. On another side the sky was flashing bright tongues of light, but I saw nothing of it, and knew not that it was taking place. Before retiring again I had to clear my bed of ashes, for the covers and pillows were being rapidly filled, and a new fall was only just beginning. The poor tree-toads, despite everything, were still chirping, and manifestly to them life was not a burden, nor even a piece of anxiety. I do not know to what extent it is true that before the eruption of May 8 the animals of the field and forest gave signs of uneasiness, and summarily left their homes in search of new quarters. Nothing of this kind appears to have been noted on this side, which is in itself not conclusive evidence denying the condition reported, and I know that on Sunday morning the blackbirds were, as usual, gambolling about the cocoanut crowns, and sending out their joyful notes to greet the rising sun. Before the morning had yet broken, news reached us that the fiery tongue of Pelée had carried death and desolation to Morne Balai.

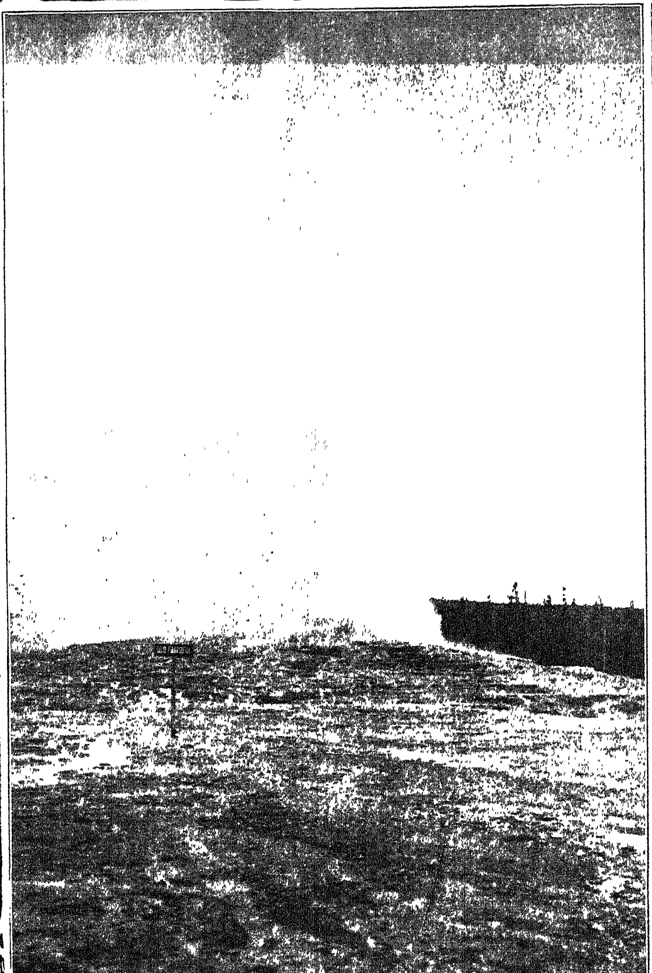
AT THE GEYSERS

By Archibald Geikie

THE next goal for which we made was the Geyser Basin of the Firehole River — a ride of two days, chiefly through forest, but partly over bare volcanic hills. Some portions of this ride led into open park-like glades in the forest, where it seemed as if no human foot had ever preceded us; not a trail of any kind was to be seen. Here and there, however, we noticed footprints of bears, and some of the trees had their bark plentifully scratched at a height of three or four feet from the ground, where, as Jack said, "the bears had been sharpening their claws." Deer of different kinds were not uncommon, and we shot enough to supply our diminishing larder. Now and then we came upon a skunk or a badger, and at night we could hear the mingled bark and howl of the wolves. Andy's rifle was always ready, and he blazed away at everything. As he rode at the head of the party, the first intimation those behind had of any game afoot was the crack of his rifle, followed by the immediate stampede of the mules and a round of execration from Jack. I do not remember that he ever shot anything save one wild duck, which immediately sank, or at least could not be found.

Reaching at length the Upper Geyser Basin, we camped by the river in the only group of trees in the immediate neighborhood that had not been invaded by

the sheets of white sinter which spread out all round on both sides of the river. There were hot springs, and spouting geysers, and steaming caldrons of boiling water in every direction. We had passed many openings by the way whence steam issued. In fact, in some parts of the route we seemed to be riding over a mere crust between the air above and a huge boiling vat below. At one place the hind foot of one of the horses went through this crust, and a day or two afterwards, repassing the spot, we saw it steaming. In this basin, however, there is one geyser which, ever since the discovery of the region, has been remarkably regular in its action. It has an eruption once every hour and a few minutes more. The kindly name of "Old Faithful" has accordingly been bestowed upon it. We at once betook ourselves to this vent. It stands upon a low mound of sinter, which, seen from a little distance, looks as if built up of successive sheets piled one upon another. The stratified appearance, however, is due to the same tendency to form basins so marked at the Hot Springs on Gardiner's River. These basins are bordered with the same banded, brightly-colored rims which running in level lines, give the stratified look to the mound. On the top the sinter has gathered into huge dome-shaped or coral-like lumps, in the midst of which lies the vent of the geyser — a hole not more than a couple of feet or so in diameter — whence steam constantly issues. When we arrived, a considerable agitation was perceptible. The water was surging up and down a short distance below, and when we could not see it for the cloud of vapor, its gurgling noise remained distinctly audible. We had not long to wait



OLD FAITHFUL

before the water began to be jerked out in occasional spurts. Then suddenly, with a tremendous roar, a column of mingled water and steam rushed up for a hundred and twenty feet into the air, falling in a torrent over the mound, the surface of which now streamed with water, while its strange volcanic colors glowed vividly in the sunlight. A copious stream of still steaming water rushed off by the nearest channels to the river. The whole eruption did not last longer than about five minutes, after which the water sank in the funnel, and the same restless gurgitation was resumed. Again, at the usual interval, another outburst of the same kind and intensity took place.

Though the most frequent and regular in its movements, "Old Faithful" is by no means the most imposing of the geysers either in the volume of its discharge or in the height to which it erupts. The "Giant" and "Beehive" both surpass it, but are fitful in their action, intervals of several days occurring between successive explosions. Both of them remained tantalizingly quiet, nor could they be provoked by throwing stones down their throats to do anything for our amusement. The "Castle Geyser," however, was more accommodating. It presented us with a magnificent eruption. A far larger body of water than at "Old Faithful" was hurled into the air, and continued to rise for more than double the time. It was interesting to watch the rocket-like projectiles of water and steam that shot through and out of the main column, and burst into a shower of drops outside. At intervals, as the energy of discharge oscillated, the column would sink a little, and then would mount up again

as high as before, with a hiss and roar that must have been audible all round the geyser basin, while the ground near the geyser perceptibly trembled. I had been sketching close to the spot when the eruption began, and in three minutes the place where I had been sitting was the bed of a rapid torrent of hot water rushing over the sinter floor to the river.

An interesting feature of the locality is the tendency of each geyser to build up a cylinder of sinter round its vent. A few of these are quite perfect, but in most cases they are more or less broken down, as if they had been blown out by occasional explosions of exceptional severity. Usually there is only one cylindrical excrescence on a sinter mound; but in some cases several may be seen with their bases almost touching each other. As the force of the geyser diminishes and its eruptions become less frequent, the funnel seems to get choked up with sinter, until in the end the hollow cylinder becomes a more or less solid pillar. Numerous eminences of this kind are to be seen throughout the region. Their surfaces are white and crumbling. They look, in fact, so like pillars of salt that one could not help thinking of Lot's wife, and wondering whether such geyser columns could ever have existed on the plains of Sodom. In a rainless climate, they might last a long time. But the sinter here, when no longer growing by fresh deposits from the escaping water, breaks up into thin plates. Those parts of the basin where this disintegration is in progress look as if they had been strewn with pounded oyster shells.

That the position of the vents slowly changes is indi-

cated on the one hand by the way in which trees are spreading from the surrounding forest over the crumbling floor of sinter, and on the other by the number of dead or dying trunks which here and there rise out of the sinter. The volcanic energy is undoubtedly dying out. Yet it remains vigorous enough to impress the mind with a sense of the potency of subterranean heat. From the upper end of the basin the eye ranges round a wide area of bare sinter plains and mounds, with dozens of columns of steam rising on all sides; while even from among the woods beyond an occasional puff of white vapor reveals the presence of active vents in the neighboring valley. A prodigious mass of sinter has, in the course of ages, been laid down, and the form of the ground has been thereby materially changed. We made some short excursions into the forest, and as far as we penetrated the same floor of sinter was everywhere traceable. Here and there a long extinct geyser mound was nearly concealed under a covering of vegetation, so that it resembled a gigantic ant-hill; or a few steaming holes about its sides or summit would bring before us some of the latest stages in geyser history.

One of the most singular sights of this interesting region was the mud volcanoes, or mud geysers. We visited one of the best of them, to which Jack gave the name of the "Devil's Paint-Pot." It lies near the margin of the Lower Geyser Basin. We approached it from below, surmounting by the way a series of sinter mounds dotted with numerous vents filled with boiling water. It may be described as a huge vat of boiling and variously colored mud, about thirty yards in diameter. At one

side the ebullition was violent, and the grayish-white mud danced up into spurts that were jerked a foot or two into the air. At the other side, however, the movement was much less vigorous. The mud there rose slowly into blister-like expansions, a foot or more in diameter, which gradually swelled up till they burst, and a little of the mud with some steam was tossed up, after which the bubble sank down and disappeared. But nearer the edge on this pasty side of the caldron the mud appeared to become more viscous, as well as more brightly-colored green and red, so that the blisters when formed remained, and were even enlarged by expansion from within, and the ejection of more liquid mud over their sides. Each of these little cones was in fact a miniature volcano with its circular crater atop. Many of them were not more than a foot high. Had it been possible to transport one unbroken, we could easily have removed it entire from its platform of hardened mud. It would have been something to boast of, that we had brought home a volcano!

THE AUTOBIOGRAPHY OF A PIECE OF COAL

(*Abridged*)

By J. E. Taylor

MY recollections go back to waving forests of tree ferns and gigantic club-mosses, as well as to a thick underwood of strange-looking plants. The name now given to this formation by geologists is the Carboniferous, and you may form some idea of the ages which have flowed away since then by the fact that no fewer than nine subsequent distinct formations and periods occurred, to say nothing of the epoch comprehending the human race. The formations newer than that to which I belong attain a vertical thickness of more than fifty thousand feet! All this mass was slowly formed by gradual deposition along old sea-bottoms and elsewhere, whilst a more than equivalent period of time was taken up in the upheaving and other processes which have elevated these rocks into their present position.

When I was born, the climate and geography of Great Britain were very different from what they now are. You must imagine a soft balmy temperature, neither too hot nor too cold. There were few ranges of hills or mountains, for these always cause a refrigeration of the atmosphere by condensing the clouds; thus hanging the sky with a curtain which shuts off a great deal of solar heat. True, right across what is now central England,

there stretched a mountainous barrier, perhaps of old Silurian rocks. Scotland and Wales were also then widely different from what these countries are at present. Instead of the grand mountainous scenery they now possess, there were long-extended saline mud-flats, thickly studded with trees now extinct, and known to the geologist by the names of sigillariæ, lepidodendra, and calamites. In fact, all the district now considered as "coal-yielding" was then similarly circumstanced. The entire area had a geographical condition similar to the marine swamps which now fringe the coast-line of the Southern States of America. To these the slowly ebbing and flowing tides had access nearly twice a day. Around the more aged trunks of these extinct trees, standing on a muddy, shallow sea-bottom, so to speak — marine worms clustered, and their coiled tubes are now occasionally found fossilized, along with the petrified vegetation to which they clung when in life. It was owing to the semi-marine, semi-terrestrial character of the area on which the luxuriant vegetation of the Carboniferous period grew, that we now find so many fossil mussels and other marine shells imbedded in the same strata.

I am told that chemists nowadays have discovered only one atom or particle of carbon associated with every thousand of the other gases forming the atmosphere. The atmosphere of the period when I was born hardly contained more. This small quantity was absorbed by the waving forests into their structure, and thus added to their solid bulk. Day by day, and year by year, each individual tree grew, so that the mass of

solidified carbon increased, but without exhausting the original store. This was constantly being furnished by volcanoes, as well as by the lowly animals of my own time.

Everything, they say, is composed of minute and cellular parts, and originally my atoms freely floated in the air as so many particles of carbon. This was before I had entered into that combination which made me part and parcel of a living tree. Once having been sucked into the leaf-pores of a lepidodendron or sigillaria, I started existence under a new form. I had now an active duty to perform, and had to assist in the growth and well-being of the tree in whose bulk I lay. But this did not prevent me from noticing the many strange objects which surrounded me. Tree lizards, not very much larger than those which now haunt the sunny banks of old England, climbed up and down the sculptured branches of the forest trees, and lived upon the marsh flies and beetles, whose "drowsy hum" was the only sound that broke upon the stillness of the primeval woods. They found a shelter in the hollow trunks of sigillariæ, in association with the pupæ of beetles and other insects. In some places they have been found fossilized together — a conserved recollection of those bygone times. Great reptiles, resembling frogs in some respects, abounded in many parts of Ireland and Scotland. In the former country was a reptile which had a snake-like form and a compressed tail, so that it very much resembled a water-serpent. No fewer than five different kinds of amphibious reptiles then lived in the very country which now boasts of its freedom from these

creatures! It is singular to notice how a great many of the fishes of the period had reptilian characters, whilst the first-introduced reptiles were not only the most lowly organized, but in many respects were related to fishes. Very frequently the salt-water reaches were visited by alligator-like animals, whose bodies were covered by hard, horny scales, held together much after the manner a slater now adopts when he tiles a house. These reptiles were five and six feet long, and were adapted to a purely marine life. They were the principal and most powerful animals of the age I am speaking of. In Ohio, no fewer than twenty-seven species of reptiles have been found, belonging to ten different genera; one has great affinities to the serpents. The atmosphere differed little from its present condition, being neither denser nor more rarified. This you may prove to yourself by the impressions of rain-drops preserved in the Carboniferous sandstones. The great drops were driven by the wind aslant, so that there is even indicated the very quarter from which the wind blew at the time! The passing shower over, the sun peeped forth from behind the dark clouds, and his heat baked the mud, and cracked it, just as he does now the bottom of a clayey pond. These sun-cracks were subsequently filled up, sometimes by sand of a different color, so that they are fossilized as truly as the shells and plants. The same sandstones yet bear the trail-markings which the marine worms left after they had crawled over them when in a soft state. Occasionally you may even come across their burrows or holes; whilst the flagstones also are impressed with ripple-marks left by the retreating tides.

Although the sea-bottom was so shallow in the neighborhood of the great forests, I should state that many miles farther out it gradually shelved deeper, until there was an area where "blue water" was attained. Previous to the formation of the coal seams, the sea was fairly alive with animals of all sorts of natural history orders and classes. Coral banks, with animals putting forth their beautifully colored tentacles, more various than the rainbow hues, stretched over many leagues of old Devonian rocks, and, as the area was slowly submerging at the time, their united labors, in the course of ages, produced no small portion of what is now termed the "Mountain or Carboniferous Limestone." Shellfish, allied to the existing nautilus, found in these purer waters, free from land sediment, the essentials of their well-being. In the limestones which their dead shells helped to form there are no fewer than thirty different species of nautilus. Then came another group of shellfish, equally near by blood, whose coils did not lie so closely together as those of the nautilus. One other class of cephalopods are now known as "orthoceratites." They were also chambered, but were straight instead of being coiled. The limestones of this age are crowded with immense numbers both of species and individuals belonging to these genera. Of them all the orthoceras was perhaps the most dreaded, partly on account of its size (some of their shells being three feet long and as thick as a man's leg), and partly on acount of their voracious habits. Fancy them, as I have frequently seen them, with their last chamber surrounded with a fringe of long arms, that would indicate no slight danger to

bathers nowadays! Hundreds of thousands of these creatures existed. Indeed, they were the scavengers of the Carboniferous seas, eating up everything that came in their way, and perhaps not particular about preying upon a weakly brother when appetite prompted them. In Scotland, in many parts of the limestones formed at this time, the strata, for hundreds of feet in thickness, are composed of hardly anything else but the accumulated shells of orthoceratites.

At the bottom of the sea in which these cephalopods lived and flourished there were gathered together immense shoals of a peculiar shell called spirifera, now extinct. Scores of species of this particular shell lived and died there, for it was the period when the family attained its maximum of existence. In fact, they occupied the place in those earlier seas that cockles and mussels do now. Their anatomy was very peculiar, each shell-fish being furnished with a peculiar coiled-up apparatus which it could protrude so as to produce currents that brought to it its food. Small, but beautiful crustaceans, of a race then fast dying out, still swarmed the waters. You may have heard of them as trilobites. The Carboniferous period saw the last of the race, and its limestones became their tomb. I am told that the geologist knows few fossils more beautiful than these little trilobites. In the same sea were hundreds of species of shells, besides, all of which thronged together to enjoy a common life. I should be lacking greatly in memory if I were not to mention a most abundant and peculiar family, allied to the star-fishes and sea-urchins of the present day — I mean the crinoids. When at rest

their tentacles closed around the body like the petals of a tulip. Again, each was fastened to a jointed stem, which anchored itself by roots to the sea-bottom. Submarine forests of these crinoids covered many square miles of the rockier portions, and their graceful outlines and motions in the water, as well as their bright colors, were sufficient to induce admiration. In Derbyshire that limestone is almost entirely composed of their broken stems, compacted so firmly as to form a marble capable of receiving a high polish. I have no doubt you may have seen mantelpieces formed of it, and have wondered at the strange forms which seem to be enclosed in the solid rock.

As these dead shells and other animal remains accumulated along the ocean floor to form a limestone that should afterwards be easily identified by their imbedded forms, almost every individual was coated by minute sea-mats. No Honiton lace of the present day ever excelled in grace and elegance that which belonged to those lowly animated beings. In the solid Carboniferous limestone you may find them festooning shells and corals. The single corals also — that is, those which did not grow in reefs, but lived solitary on the sea-bottom — were not inferior in beauty to any now existing. Their fringe of gorgeously colored tentacles made them appear like so many animated flowers; and thus the dark caves of ocean then bore many a flower that was born to blush unseen. Slowly, through countless thousands of years, the Carboniferous limestone increased to its present thickness, principally by the accumulation of dead shells. The sea-water contained more or less of carbon-

ate of lime, which the shell-fish absorbed in order to build their dwellings, just as the trees did carbon that they might form wood. In this way the minute particles became ultimately condensed into rock masses. Meantime, the water was animated by little creatures that would have evaded human eyesight, although their forms were not a whit less elegant and graceful than those of their larger neighbors. Their tiny shells fell to the sea-bottom, and there formed a limy mud, which acted as a fine cement for the bigger fossils. As time passed on, the sea actually became shallower, by reason of the vast numbers of organisms lying on its floor. The weight of sea-water pressed them into a solid limestone rock, such as you now behold it. Can you wonder, after this, that such a deposit should take a high polish when worked, or that the marble thus produced should be speckled and marked by so many strange forms as you see it in your mantelpieces or pillars?

In the shallower waters of the sea, and sometimes even in the marine lagoons where the trees grew, multitudes of strangely clad fishes swarmed. From four or five feet in length to thousands no bigger than the common stickleback, nearly all were covered with enamel plates instead of horny scales. Indeed, horny-scaled fishes did not come into existence for ages afterwards. In many parts of Lancashire, in the shales which overlie the coal-seams, these shining enameled plates may be turned up by the thousand. The smaller fishes haunted the shallower lagoons overhung by club-mosses and ferns. When the muddy bottoms of these reaches and lagoons became afterwards hardened into

coal-shale, the dead fishes lying there, whose hard covering had protected them from decay, were entombed and passed into a fossil state.

But what tongue can describe the vegetable wonders of the forests where I grew? The woods were so thick, and the gloom so impenetrable in consequence, that it required a keen eye to make out individual peculiarities. Fancy lepidodendra four or five feet in diameter, and as much as fifty or sixty feet high, and yet nothing but gigantic "club-mosses"! Their long leafy ribbons waved like the leaves of the aspen, and, where these had fallen off, the bark was most gracefully and geometrically patterned from their attachment. Thirty or forty different sorts of these immense club-mosses existed at the same time, each characterized by different leaves and bark. The gigantic sigillariæ were nearly related to them, the main difference being their longer leaves, straighter stems, and the larger marks left on the bark. The roots, also, of this latter class of trees were very peculiar, and stretched through the mud on every side, seeking a firm foundation for the tree to which they belonged. Shooting many feet above these great club-mosses were high "horse-tails," as easily distinguished from the rest as the aspen-poplar nowadays is from oak and elm. These are called calamites, and truly they were extraordinary objects. You have only to magnify the little "horse-tails" now growing in ditches, until you see them fifty and sixty or more feet high, and you will have the best restoration of these calamites that can be imagined. There were many species, characterized by fluted joints, and by difference of foliage. Here and there, but more

sparsely scattered, were graceful tree-ferns, whose former fronds had left great scars on each side the trunk. The higher grounds were occupied by peculiar species of pine, bearing great berries as big as crab-apples. The humid morass was densely covered by a thick underwood of smaller ferns, which grew there in rank abundance. The equable temperature, rich soil, and humid atmosphere were just the needful accessories to the growth of vegetation of the class I have mentioned. It consequently flourished at a rate of which we can form but a poor idea from the present. I mentioned before that there was a slow sinking or submergence going on. Occasionally the tides brought up silt and strewed it over the decomposing vegetation. In fact many of the forests were actually buried thus, and their trunks are frequently met with standing erect in solid sandstone rock. As time elapsed, another forest grew on the site of the older, to be buried up in its turn. During countless ages this alternate growth and covering up went on, until in some places there are no fewer than one hundred different seams of coal, under each of which you may see a clay full of the roots and rootlets of the vegetation I have been mentioning.

After this vegetation had been thus collected, chemical changes began to take place. The mass heated and turned black, just as a stack of hay does now when it has been packed in a damp state. By and by, it was transmuted into a pulpy condition, wherein almost all traces of vegetable structure became lost. It afterwards changed into a solid subcrystalline mass, and obtained the jetty, semi-cubical character it now presents. As

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IN AN ANTHRACITE COAL MINE

many of the tissues of coniferous trees contain more or less of silex, which is indestructible, it follows that when coal is burned, this drops out of the grate as a white ash.

The ancient vegetation of the coal period grew by virtue of the stimulus of the sunlight. The heat and light induced growth, and thus even a piece of coal represents so much fossil sunshine; so that, when men light their fires or manufacture their gas, they are but setting free the light and heat of the sun which poured down on the old Carboniferous forest, and were stored up by the vegetation in their tissues. Nay, more, botanists will tell you that the three primary colors of light are sure to be developed at some time or another in the history of every plant or tree — in the blue and yellow which form the green of the leaves, and in the red of the fruit or russet of the bark. Just so with the fossil vegetation termed coal. The very aniline colors obtained from coal tar are the restoration of the primary colors which the ancient vegetation stored up from the light.

THE LIME IN THE MORTAR

(Abridged)

By Charles Kingsley

I SHALL presume in all my readers some slight knowledge about lime. I shall take it for granted, for instance, that all are better informed than a certain party of Australian black fellows were a few years since.

In prowling on the track of a party of English settlers, to see what they could pick up, they came — oh, joy! — on a sack of flour, dropped and left behind in the bush at a certain creek. The poor savages had not had such a prospect of a good meal for many a day. With endless jabbering and dancing, the whole tribe gathered round the precious flour-bag with all the pannikins, gourds, and other hollow articles they could muster, each of course with a due quantity of water from the creek therein, and the chief began dealing out the flour by handfuls, beginning of course with the boldest warriors. But, horror of horrors, each man's porridge swelled before his eyes, grew hot, smoked, boiled over. They turned and fled, man, woman, and child, from before that supernatural prodigy; and the settlers coming back to look for the dropped sack, saw a sight which told the whole tale. For the poor creatures, in their terror, had thrown away their pans and calabashes, each filled with that which it was likely to contain, seeing that the sack itself had contained, not flour, but quicklime. In mem-

ory of which comi-tragedy, that creek is called to this day "Flour-Bag Creek."

Now I take it for granted that you are all more learned than these fellows, and know quicklime from flour. But still you are not bound to know what quicklime is. Let me explain to you.

Lime, properly speaking, is a metal, which goes among chemists by the name of calcium. But it is formed, as you all know, in the earth, not as a metal, but as a stone, as chalk or limestone, which is a carbonate of lime; that is, calcium combined with oxygen and carbonic acid gases.

In that state, it will make, if crystalline and hard, excellent building stone. The finest white marble, like that of Carrara in Italy, of which the most delicate statues are carved, is carbonate of lime altered and hardened by volcanic heat. But to make mortar of it, it must be softened and then brought into a state in which it can be hardened again; and ages since, some man or other, discovered the art of making lime soft and hard again; in fact, of making mortar. The discovery was probably very ancient; and made, probably like most of the old discoveries, in the East, spreading westward gradually. The earlier Greek buildings are cyclopean, that is, of stone fitted together without mortar. The earlier Egyptian buildings, though the stones are exquisitely squared and polished, are put together likewise without mortar. So, long ages after, were the earlier Roman buildings, and even some of the later.

If limestone be burned, or rather roasted, in a kiln, the carbonic acid is given off — as you may discover by

your own nose; as many a poor tramp has discovered too late, when, on a cold winter night, he has lain down by the side of the burning kiln to keep himself warm, and has waked in the other world, stifled to death by the poisonous fumes.

The lime then gives off its carbonic acid, and also its water of crystallization, that is, water which it holds (as do many rocks) locked up in it unseen, and only to be discovered by chemical analysis. It is then anhydrous — that is, waterless — oxide of lime, what we call quick-lime; and then, as you may find if you get it under your nails or into your eyes, will burn and blister like an acid.

This has to be turned again into a hard and tough artificial limestone, in plain words, into mortar; and the first step is to slack it — that is, to give it back the water which it has lost, and for which it is as it were thirsting. So it is slacked with water, which it drinks in, heating itself and the water till it steams and swells in bulk, because it takes the substance of the water into its own substance.

Then it must be made to set, that is, to return to set, that is, to return to limestone, to carbonate of lime, by drinking in the carbonic acid from water and air, which some sorts of lime will do instantly, setting at once, and being therefore used as cements. But the lime usually employed must be mixed with more or less sand to make it set hard: a mysterious process, of which it will be enough to tell the reader that the sand and lime are said to unite gradually, not only mechanically — that is, by sticking together; but also in part chemically — that is,

by forming out of themselves a new substance, which is called silicate of lime.

Be that as it may, the mortar paste has now to do two things; first to dry, and next to take up carbonic acid from the air and water, enough to harden it again into limestone: and that it will take some time in doing. A thick wall, I am informed, requires several years before it is set throughout, and has acquired its full hardness, or rather toughness; and good mortar, as is well known, will acquire extreme hardness with age, probably from the very cause that it did when it was limestone in the earth. For, as a general rule, the more ancient the strata in which the limestone is found, the harder the limestone is; except in cases where volcanic action and earthquake pressure have hardened limestone in more recent strata, as in the case of the white marbles of Carrara in Italy, which were hardened by the heat of intruded volcanic rocks.

But now: what is the limestone? and how did it get where it is — not into the mortar, I mean, but into the limestone quarry. Let me tell you by leading you to places unknown to most. Let me lead you in fancy to some island in the Tropic seas.

The ship will have to lie-to, and anchor if she can; it may be a mile, it may be only a few yards, from the land, for between it and the land will be a line of breakers, raging in before the warm trade-wind. And this marks the edge of the coral reef.

You will have to go ashore in a boat, over a sea which looks unfathomable, and which may be a mile or more in depth, and search for an opening in the reef, through

which the boat can pass without being knocked to pieces.

You find one; and in a moment, what a change! The deep has suddenly become shallow; the blue white, from the gleam of the white coral at the bottom. But the coral is not all white, only indeed a little of it; for as you look down through the clear water, you find that the coral is starred with innumerable live flowers, blue, crimson, gray, every conceivable hue; and that these are the coral polyps, each with its ring of arms thrust out of its cell, who are building up their common habitations of lime.

The bottom, just outside the reef, is covered with lime mud, which the surge wears off the reef; and if you have a dredge on board and try a haul of that mud as you row home, you may find animal forms rooted in it which will delight the soul of a scientific man. One, I hope, would be a brachiopod, a family with which the ancient seas once swarmed, but which is rare now all over the world, having been supplanted and driven out of the seas by newer and stronger forms of shelled animals.

The other might be a live crinoid, an exquisite starfish, with long and branching arms, but rooted in the mud by a long stalk, and that stalk throwing out barren side branches, the whole a living plant of stone. You may see in museums specimens of this family, now so rare, all but extinct. And yet fifty or a hundred different forms of the same type swarmed in the ancient seas; whole masses of limestone are made up of little else but the fragments of such animals.

But we have not landed yet on the dry part of the reef. Let us make for it, taking care meanwhile that we do not get our feet cut by the coral or stung as by nettles by the coral insects. We shall see that the dry land is made up entirely of coral, ground and broken by the waves, and hurled inland by the storm, sometimes in huge boulders, mostly as fine mud; and that, under the influence of the sun and of the rain, which filters through it, charged with lime from the rotting coral, the whole is setting, as lime sets, into rock. And what is this? A long bank of stone standing up as a low cliff, ten or twelve feet above high-water mark. It is full of fragments of shell, of fragments of coral, of all sorts of animal remains; and the lower part of it is quite hard rock. Moreover, it is bedded in regular layers, just such as you see in a quarry. But how did it get there? It must have been formed at the sea-level, some of it, indeed, under the sea; for here are great masses of madrepore and limestone corals imbedded just as they grew. What lifted it up?

It was supposed at first that when a coral island rose steeply to the surface of the sea out of blue water, perhaps a thousand fathoms or more, that fact was plain proof that the little coral polyps had begun at the bottom of the sea, and in the course of ages, built up the whole island an enormous depth. But it soon came out that this theory was not correct; for the coral polyps cannot live and build save in shallow water — say, in thirty to forty fathoms. Indeed, some of the strongest and largest species work best at the very surface, and in the cut of the fiercest surf. And so arose a puzzle as to

how the coral rock is often found of vast thickness, which Mr. Darwin explained. His theory was, and there is no doubt now that it is correct, that in these cases the sea-bottom is sinking; that as it sinks, carrying the coral beds down with it, the coral dies, and a fresh live crop of polyps build on the top of the houses of their dead ancestors; so that, as the depression goes on, generation after generation builds upwards, the living on the dead, keeping the upper surface of the reef at the same level, while its base is sinking downward into the abyss.

By applying this theory to the coral reef of the Pacific Ocean, the following interesting facts were made out: —

That where you find an island rising out of deep water, with a ring of coral round it, a little way from the shore — or, as in Eastern Australia, a coast with a fringing reef — that is a pretty sure sign that that shore, or mountain, is sinking slowly beneath the sea. That where you find, as you often do in the Pacific, a mere atoll, or circular reef of coral, with a shallow pond of smooth water in the center, and deep sea round, that is a pretty sure sign that the mountain-top has sunk completely into the sea, and that the corals are going on building where its peak once was.

And more. On working out the geography of the South Sea Islands by the light of this theory of Mr. Darwin's, the following extraordinary fact has been discovered: —

That over a great part of the Pacific Ocean sinking is going on, and has been going on for ages; and that the

greater number of the beautiful and precious South Sea Islands are only the remains of a vast continent or archipelago which once stretched for thousands of miles between Australia and South America.

Now, applying the same theory to limestone beds, which are only fossil coral reefs, we have a right to say, when we see in England, Scotland, Ireland, limestones several thousand feet thick, that while they were being laid down as coral reefs, the sea bottom, and probably the neighboring land, must have been sinking to the amount of their thickness — to several thousand feet — before that later sinking which enabled several hundred feet of millstone grit to be laid down on the top of the limestone.

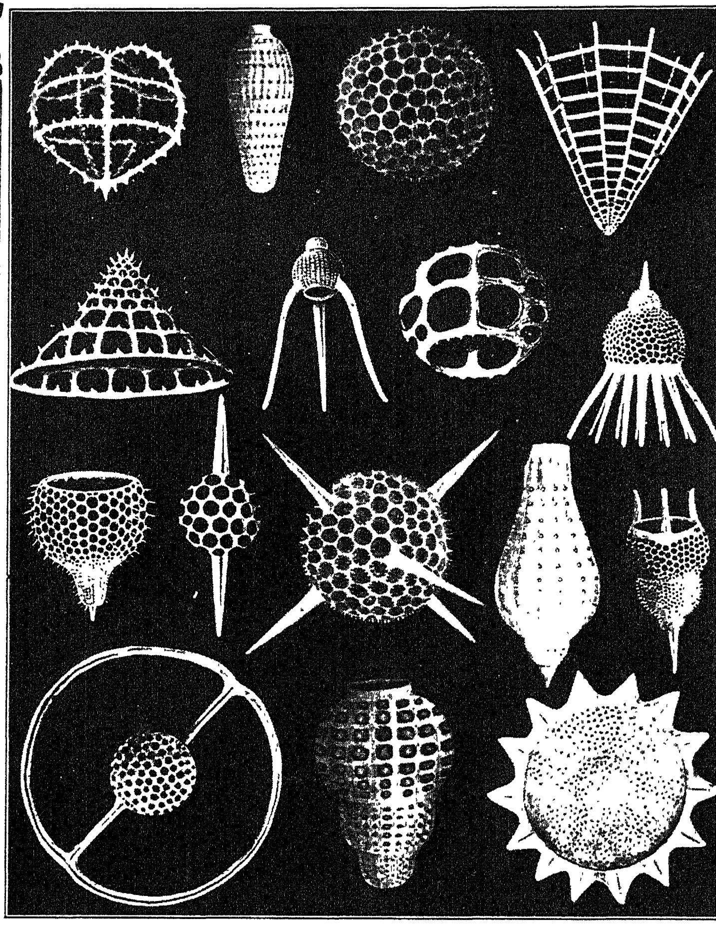
This millstone grit is a new and very remarkable element in our strange story: From Derby to Northumberland it forms vast and lofty moors, capping the highest limestone hills with its hard, rough, barren, and unfossiliferous strata. Wherever it is found, it lies on the top of the "mountain" or carboniferous limestone. Almost everywhere, where coal is found in England, it lies on the millstone grit. The three deposits pass more or less, in many places, into each other; but always in the order of mountain limestone below, millstone grit on it, and coal on that again.

Now what does its presence prove? What but this? That after the great coral reefs were laid down, some change took place in the sea bottom, and brought down on the reefs of coral sheets of sand, which killed the corals and buried them in grit. Does any reader wish for proof of this, Let him examine the flinty beds which

so often appear where the bottom of the millstone grit is passing into the top of the mountain limestone. He will find layers in those beds, of several feet in thickness, as hard as flint, but as porous as sponge. On examining their activities, he will find them to be simply hollow casts of innumerable joints of crinoids, so exquisitely preserved, even to their most delicate markings that it is plain they were never washed about on a beach, but have grown where, or nearly where, they lie. What, then, has happened to them? They have been killed by the sand. The soft parts of the animals have decayed, letting the 140,000 joints (more or less) belonging to each animal fall into a heap, and be imbedded in the growing sand-rock; and then, it may be long years after, water filtering through the porous sand has removed the lime of which the joints were made, and left their perfect casts behind.

So much for the millstone grits. How long the deposition of sand went on, how long after it that second deposition of sands took place which goes by the name of the lower coal measures, we cannot tell. But it is clear at least that parts of that ancient sea were filling up and becoming dry land. For coal, or fossilized vegetable matter, becomes more and more common as we ascend in the series of beds; till at last in the upper coal measures the enormous wealth of vegetation which grew, much of it, where it is now found, proves the existence of some such sheets of fertile and forest-clad lowland.

Thousands of feet of rich coral reef; thousands of feet of barren sands; then thousands of feet of rich



WHAT ROCKS ARE MADE OF

These minute shells are the raw material, enormously magnified, of many rocks. To the naked eye they look like fine white powder. A million of them would go into a thimble.

alluvial forest; — and all these sliding into each other, if not in one place, then in another, without violent break or change: this is the story which the lime in the mortar and the coal on the fire — between the two — reveal.

HOW FOSSILS ARE PRESERVED

(Abridged)

By H. N. Hutchinson

AIR and water are great destroyers of animal and vegetable substances from which life has departed. The autumn leaves that fall by the wayside soon undergo change, and become at last separated or resolved into their original elements. In the same way, when any wild animal, such as a bird or rabbit, dies in an exposed place, its flesh decays under the influence of rain and wind, so that before long nothing but dry bones is left. If water and air be excluded, it is wonderful how long even the most perishable things may be preserved from this otherwise universal decay. In the Edinburgh Museum of antiquities may be seen an old wooden cask of butter that has lain for centuries in peat — which substance has a curious preservative power; and human bodies have been dug out of Irish peat with the flesh well preserved, which, from the nature of the costume worn by the person, we can tell to be very ancient. Meat packed in tins, so as to be entirely excluded from the air, may be kept a very long time, and will be found to be quite fresh and fit for use.

But air and water have a way of penetrating into all sorts of places, so that in nature they are almost everywhere. Water can slowly filter through even the hardest

rocks, and since it contains dissolved air, it causes the decay of animal or vegetable substances. Take the case of a dead leaf falling into a lake, or some quiet pool in a river. It sinks to the bottom, and is buried up in gravel, mud, or sand. Now, our leaf will stand a very poor chance of preservation on a sandy or gravelly bottom, because these materials, being porous, allow the water to pass through them easily. But if it settles down on fine mud it may be covered up and become a fossil. In time the soft mud will harden into clay or shale, retaining a delicate impression of the leaf; and even after thousands of years, the brown body of the leaf will be there, only partly changed. In the case of the plants found in coal, the lapse of ages since they were buried up has been so great, and the strata have been so affected by the great pressure and by the earth's internal heat, that certain chemical changes have converted leaves and stems into carbon and some of its compounds, much in the same way that, if you heat wood in a closed vessel, you convert it into charcoal, which is mostly carbon. The coal we burn in our fires is entirely of vegetable origin, and every seam in a coal mine is a buried forest of trees, ferns, reeds, and other plants.

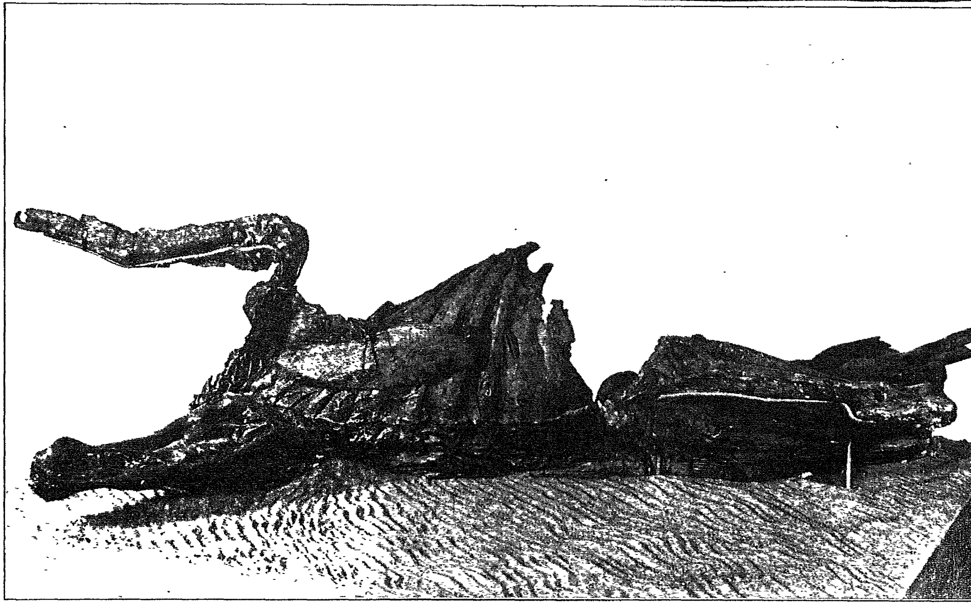
The reader will understand how it is that rocks composed of hardened sand or gravel, sandstones, and conglomerates, contain but few fossils; while, on the other hand, such rocks as clay, shale, slate, and limestone often abound in fossils, because they are formed of what was once soft mud, that sealed up and protected coral, shell-fish, sea-urchins, fishes, and other marine animals. Had they been covered up in sand, the chances are that

percolating water would have slowly dissolved the shells and corals, the hard coats of the crabs, and bones of the fishes, all of which are composed of carbonate of lime; and we know that is a substance easily dissolved by water.

The soft parts of animals, as we have said before, cannot be preserved in a fossil state; but, as if to compensate for this loss, we sometimes meet with the most faithful and delicate impressions. Thus, cuttle-fishes have, in some instances, left, on the clays which buried them up, impressions of their soft, long arms, or tentacles, and as the mud hardened into solid rock, the impressions are fixed imperishably. Even soft jellyfishes have left their mark on certain rocks! At a place in Bavaria, called Solenhofen, there is a remarkably fine-grained limestone containing a multitude of wonderful impressions. This stone is well known to lithographers, and is largely used in printing. On it the oldest bird has left its skeleton and faithful impressions of its feathers.

The footprints of birds and reptiles are by no means uncommon. Such records are most valuable, for a great deal may be learned from even a footprint as to the nature of the animal that made it.

Granite and basalt do not contain fossils. They have been mainly formed by the action of great heat, and were forced up to the surface of the earth by pressure from below. As they slowly cooled, the mineral substances of which they were formed gradually crystallized, and it is this crystalline state, together with the signs of movement, that tells us of their once heated state. Such rocks are said to be of igneous origin (Latin, *ignis*, fire).



THE DINOSAUR MUMMY

Skeleton of a Trachodon, preserving the skin impression over a large part of the body. This animal was about fifteen feet high, and lived in the "Age of Reptiles" three million years ago. Photograph reproduced by courtesy of the American Museum of Natural History, New York City

But nearly all other rocks were formed by the action of water — that is, under water — and hence are known to geologists as aqueous deposits (*aqua*, water). They may be considered as sediments that slowly settled down in seas, lakes, or at the mouths of rivers. Such deposits are in the course of being formed at the present day. All round our coasts mud, sand, and gravel are being constantly accumulated, layer by layer. These materials are constantly being swept off the land by the action of rain and rivers, and carried down to the sea. Perhaps, when staying at the seaside, you may have noticed, after rainy and rough weather, how the sea, for some distance from the shore, is discolored with mud — especially at the mouth of a river. The sand, being heavy, soon sinks down, and this is the reason why sandbars so frequently block the entrance to rivers. Then again, the waves of the sea beat against the seashore and undermine the cliffs, bringing down great fragments, which after a time are completely broken up and worn down into rounded pebbles, or even fine sand and mud. It is very easy to see that in this way large quantities of sand, gravel, and mud are continually supplied to our seas. We can picture how they will settle down; the sand not far from the shore, and the fine mud farther out to sea. When the rough weather ceases, the river becomes smaller and flows less rapidly, so that when the coarse débris of the land has settled down to form layers, or strata, of sand and gravel, then the fine mud will begin to settle down also, and will form a layer overlying them or farther out. Thus we learn, from a little description of what is now going on, how layers of sand and mud, such as we

see in a quarry, were made thousands and thousands of years ago.

When we think of all the big rivers and small streams continually flowing into the sea, we shall begin to realize what a great work rain and rivers are doing in making the rocks of the future. If, at a later period, a slight upheaval of the sea-bed were to take place so as to bring it above water, and such is very likely, these materials would be found neatly arranged in layers, and more or less hardened into solid rock.

There is another kind of rock frequently met with, the building up of which cannot be explained in the way we have pointed out; and that is limestone. Geologists have good reasons for believing that it has been gradually formed in the deeper and clearer parts of oceans by the slow accumulation of marine shells, corals, and other creatures, whose bodies are partly composed of carbonate of lime.

Just as rivers are mainly responsible for bringing down to the sea the materials of which rocks are made, so these universal carrying agents are the means by which the bodies of many animals that live in the plains, over which they wander, are brought to their last resting-place. We have only to consult the records of great floods to see what fearful havoc they sometimes make among living things, and how the dead bodies are swept away.

Great floods rise rapidly, so that the herds of wild animals pasturing on grassy plains are surprised by the rising water, are hurried along, and so drowned. When dead they sink to the bottom, and may, in some cases,

be buried up in the débris hurried along by the river; but as a rule their bodies, being swollen by the gases formed by decomposing flesh, rise again to the surface, and consequently may be carried along for many a mile, till they reach some lake, or perhaps right down to the mouth of a river, and so may be taken out to sea.

In tropical countries, where very heavy rains fall at times, and rivers become rapidly swollen, floods are a great source of danger to man and beast. But probably the greater number of the bodies of animals thus drowned find their way into lakes, through which rivers flow, and never reach the sea; and if the growth of sediment in such lakes goes on fairly rapidly, their remains may be buried up, and so preserved. But in many cases the bones fall one by one from the floating carcass, and so may in that way be scattered at random over the bottom of the lake, or the bed of a river at its mouth. In hot countries, such bodies, on reaching the sea, run a great chance of being instantly devoured by sharks, alligators, and other carnivorous animals. But during very heavy floods, the waters that reach the sea are so heavily laden with mud, that these predacious animals are obliged to retire to some place where the waters are clear, so that at such times the dead bodies are more likely to escape their ravages; and, at the same time, the mud with which the waters are charged falls so rapidly that it may quickly cover them up.

Sedimentary rocks found in lakes, then, are much more likely to contain the remains of land animals than those that were formed in seas, and they are more likely to be in a complete state of preservation. Within the

last century, five or six small lakes in Scotland, which had been artificially drained, yielded the remains of several hundred skeletons of stags, oxen, boars, horses, sheep, dogs, hares, foxes, and wolves. There are two ways in which these animals may have met with a watery grave. In the first place, they may have got mired on going into the water, or in trying to land on the other side, after swimming across. Any one who knows Scotch lakes will be familiar with the fact that their margins are often most treacherous ground for bathers. The writer has more than once found it necessary to be very cautious on wading into a lake while fishing or in search of plants. Secondly, when such lakes are frozen over in winter, the ice is often very treacherous in consequence of numerous springs; and animals attempting to cross may be easily drowned. No remains of birds were discovered in these lakes, in spite of the fact that, until drained, they were largely frequented by water-fowl. But it must be remembered that birds are protected by their powers of flight from perishing in such ways as other animals frequently do. And, even should they die on the water, their bodies are not likely to be submerged; for, being light and feathery, they do not sink, but continue to float until the body rots away or is devoured by some creature such as a hungry pike. For these reasons the remains of birds are unfortunately very rare in the stratified rocks; and hence our knowledge of the bird life of former ages is slight.

IN THE DAYS OF THE MAMMOTH

(*Abridged*)

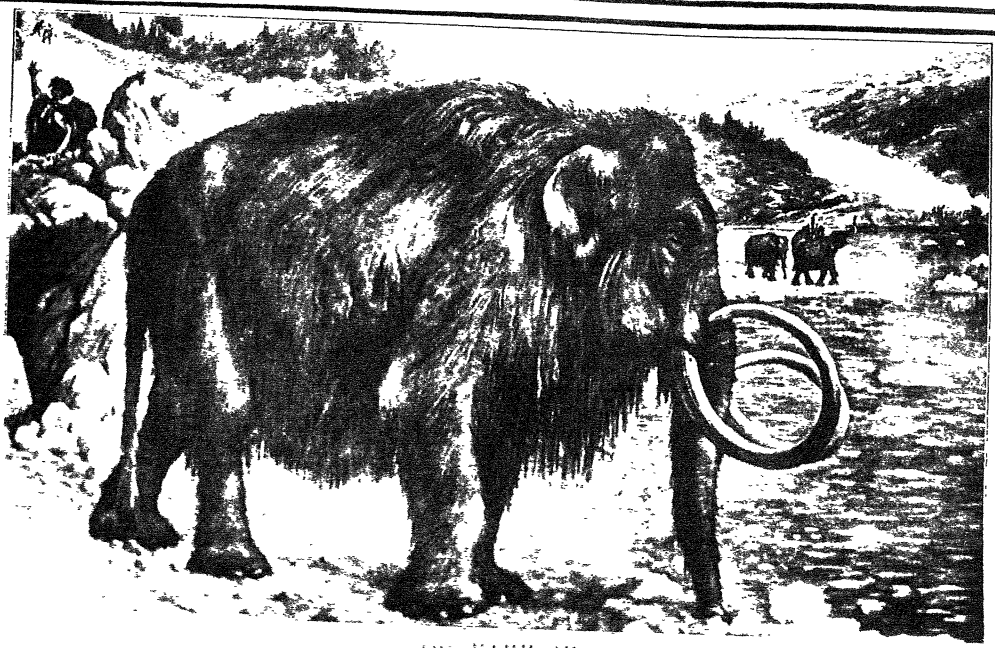
By Alexander Winchell

THIS (the mammoth) and the mastodon are the beasts of which our Indians preserve some distinct traditions. This is the beast once hunted by the prehistoric inhabitant of Europe. It was the figure of such game that European man in the Stone Age sometimes etched on plates of ivory. In at least two such instances such outlines, traced on ivory, have been taken from mounds in the Mississippi Valley.

History has preserved no mention of the existence of the mammoth in the living state; but its bones are scattered over the whole of Europe and northern Asia as far as Behring Strait; even on the American side of the strait they occur in similar abundance. But it was, according to prevailing scientific opinion, a somewhat different species of mammoth which left its remains throughout the United States and even as far as Mexico and Central America. Still another species ranged from Honduras to Peru. Like modern elephants, the mammoths probably delighted in water and mire, and sometimes indulged, like the rhinoceros and the pig, in the dirty habit of wallowing in the mud. This instinct sometimes tempted the huge creatures into treacherous bogs, in which they seem sometimes to have sunk beyond recovery; for their bones are frequently preserved in

beds of peat, and the skeleton is occasionally found in an erect position. Their tusks occur in northern Russia in such abundance as to supply an important part of the ivory of commerce. It is said that Siberian ivory constitutes the principal material on which the Russian ivory-turner works. Alaska also affords considerable supplies.

Strange as it may seem, the mammoth, whose congener, the elephant, is remarkably sensitive to cold, once abounded throughout the Arctic latitudes of the two worlds. More than a hundred years ago not only their ivory but their carcasses were known to exist in Siberia, embedded in solid ice. The first discovery was on the borders of the Alaseia River, which flows into the Arctic Ocean beyond Indigirska. The body was still standing erect, and was almost perfect. The skin remained in place, and the hair and fur were still attached in spots. In 1772 the body of a perfect two-horned rhinoceros, covered with hair, was found preserved in frozen gravel near the Vilhoni or Wiljui, a tributary of the Lena, in latitude 64°. The head and feet of the animal — also related to tropical species — are preserved in St. Petersburg. The most celebrated discovery was made in 1799. A Tungusian fisherman named Schumachoff was exploring along the coast of the frozen ocean for ivory. He was near the mouth of the Lena River, in latitude 70°, when he noticed, in a huge block of clear glacier ice, a dark object embedded too deeply to permit a half savage curiosity to feel tempted to explore. In 1801 the melting of the ice had exposed a portion of the very carcass of the animal whose ivory was strewed



among those frozen shores. In 1803 it had become completely disengaged by the dissolution of the ice. In 1804 the Tungusian cut the tusks, weighing three hundred pounds, from the head, and disposed of them for fifty roubles to an ivory merchant. In 1806 Mr. Adams, who was collecting for the Imperial Museum at St. Petersburg, found the carcass still on the shore, but greatly mutilated. It appeared that the Yakutski had actually regaled their dogs upon the flesh; and bears, wolves, wolverines, and foxes had gladly feasted upon it! Fresh elephant steaks preserved ten thousand years in Nature's unequaled refrigerator! Thus this priceless relic of a prehistoric world was allowed to waste away. But it was not completely lost to science; for, except one foreleg, the skeleton remained perfect. A large part of the skin had also escaped destruction, together with one of the ears, which still preserved its characteristic tuft of hairs. The skin was of a dark tint, and was covered with reddish wool an inch in length, interspersed with reddish-brown hairs four inches long, and sparser black bristles twelve to sixteen inches long. Dampness, however, had destroyed large portions, and others had been trodden into the earth by bears. Everything of value was now collected, including more than thirty pounds of fur; the tusks were repurchased, and the whole was transported to St. Petersburg, where the mounted skeleton at present stands, in the Imperial Museum — the skin still remaining attached to the head and feet. This individual was nine feet high and sixteen feet long, exclusive of the tusks.

Other discoveries have been made more recently. In

1843 a mammoth was found on the Tas, between the Obi and the Yenesei, in so perfect a state that the bulb of the eye is still preserved in the museum at Moscow.

It is impossible to refrain from speculating on the nature of the events which resulted in the burial of entire mammoths in glacier ice. That the climate in which they lived was not tropical, like that of Africa or India, may be regarded as proved by the presence of the fur in which these animals were clothed. That it was not similar to the existing climate of northern Siberia is apparent from the consideration that such a climate would not yield the requisite supply of vegetation to sustain their existence. More especially would forest vegetation be wanting, which seems to have been designed as the main reliance for proboscidians. Northern Siberia must, therefore, have possessed a temperate climate. If the change to an Arctic climate had been gradual, the herds of mammoths would probably have slowly migrated southward; or, if no actual migration occurred, the extinction of the mammoth population would have been distributed over many years, and the destruction of individuals would have taken place at temperatures which were still insufficiently rigorous to preserve their carcasses for a hundred ages. Whole herds of mammoths must have been overwhelmed by a sudden invasion of Arctic weather. Some secular change produced an unprecedented precipitation of snow. We may imagine elephantine communities huddled together in the sheltering valleys and in the deep defiles of the rivers, where, on previous occasions, they had found that protection which carried them safely through

wintry storms. But now, the snowfall found no pause. Like cattle overwhelmed in the gorges of Montana, the mammoths were rapidly buried. By precipitation and by drifting, fifty feet of snow, perhaps, accumulated above them. They must perish; and with the sudden change in the climate, their shroud of snow would remain wrapped about them through all the mildness of the ensuing summer. The fleecy snow would become granular; it would be *névé* or *firn*, as in the glacier sources of the Alps. It would finally become solid ice — compact, clear, and sea-green in its limpid depths. It would be a glacier; and so it would travel down the gorges, down the valleys toward the frozen ocean, sweeping buried mammoths bodily in its resistless stream. Thus, in the course of ages, their mummied forms would reach a latitude more northern than that in which they had been inhumed. It may even have been the case that living mammoths lingered in the country which had witnessed the snowy burial of herds of their fellows. Some must have escaped the first great snow deluge, and there must have been a return of sunny days, during which they could seek to resuscitate their famished bodies; and spring must have come back at last, and another hope-inspiring summer — cheering, but short and illusory. And if a secular pause in the severity of the climate ensued, a few survivors may have lingered for many years. But winter, dire and permanent, was on the march, and the record which it has left declares that the mammoth population struggled in vain against the despotism of frost, and that the empire which was set up has crumbled only under the attacks of many thousand summers.

Geological evidences of a great and somewhat sudden change of climate throughout the North Temperate Zone, in times geologically recent, are too familiar to require more than a mere mention. The greater part of Europe, and all America to the latitude of 36° were once buried beneath sheets of glacier ice. In Europe we have the evidence of the presence of man while the continental glaciers were flooding the rivers of France by their rapid dissolution. At the same time the mammoth was there. While thousands of his fellow mammoths were lying frozen and stark in the icy cemeteries of the North, a few of the giants of a former age had chanced to dwell in latitudes which perpetual snow had not invaded. These were a part of the game which the primeval inhabitants of Europe pursued. Of his ivory they made handles for their implements and weapons. On his ivory they etched figures of the maned and shaggy proboscidian, of which neither history nor tradition has preserved the memory. The bones and teeth of the mammoth are strewed through all the cavern homes and sequestered haunts of the oldest tribes who hunted and fought upon the plains and along the valleys of Europe.

The reader will inquire: "How many years have elapsed since Siberian elephants were encased in ice? How many since their survivors thundered through the forests of England and Central Europe before the chase of the human hunter?" The present writer is of the opinion that the geological events which have taken place since the epoch of general glaciation do not demand over ten thousand years.

WHAT TO SEE ON THE MOON

(*Abridged*)

By Garrett P. Serviss

IF the reader will view the moon with a first-rate field glass, he will perceive that the true nature of the surface of the lunar globe can be readily discerned with such an instrument. Even a small opera glass will reveal much to the attentive observer of the moon; but for these observations the reader should, if possible, make use of a field glass, and the higher its power the better.

Of course the first thing the observer will wish to see will be the mountains of the moon, for everybody has heard of them, and the most sluggish imagination is stirred by the thought that one can look off into the sky and behold "the eternal hills" of another planet as solid and substantial as our own. But the chances are that, if left to their own guidance, ninety-nine persons out of a hundred would choose exactly the wrong time to see these mountains. At any rate, that is my experience with people who have come to look at the moon through my telescope. Unless warned beforehand, they invariably wait until full moon, when the flood of sunshine poured perpendicularly upon the face of our satellite conceals its rugged features as effectually as if a veil had been drawn over them. Begin your observations with the appearance of the narrowest crescent of

the new moon, and follow it as it gradually fills, and then you will see how beautifully the advancing line of lunar sunrise reveals the mountains, over whose slopes and peaks it is climbing, by its ragged and sinuous outline. The observer must keep in mind the fact that he is looking straight down upon the tops of the lunar mountains. It is like a view from a balloon, only at a vastly greater height than any balloon has ever attained. Even with a powerful telescope the observer sees the moon at an apparent distance of several hundred miles, while with a field glass, magnifying seven diameters, the moon appears as if thirty-five thousand miles off. Recollect how when seen from a great height the rugosities of the earth's surface flatten out and disappear, and then try to imagine how the highest mountains on the earth would look if you were suspended thirty-five thousand miles above them, and you will, perhaps, rather wonder at the fact that the moon's mountains can be seen at all.

It is the contrast of lights and shadows that not only reveals them to us, but enables us to measure their height. On the moon shadows are very much darker than upon the earth, because of the extreme rarity of the moon's atmosphere, if indeed it has any atmosphere at all. By stepping around the corner of a rock there, one might pass abruptly from dazzling noonday into the blackness of midnight. The surface of the moon is extraordinarily rough and uneven. It possesses broad plains, which are probably the bottoms of ancient seas that have now dried up, but these cover only about two fifths of the surface visible to us, and most of the remaining three fifths are exceedingly rugged and moun-

tainous. Many of the mountains of the moon are, foot for foot, as lofty as the highest mountains on the earth, while all of them, in proportion to the size of the moon's globe, are much larger than the earth's mountains. It is obvious, then, that the sunshine, as it creeps over these Alpine landscapes in the moon, casting the black shadows of the peaks and craters many miles across the plains, and capping the summits of lofty mountains with light, while the lower regions far around them are yet buried in night, must clearly reveal the character of the lunar surface. Mountains that cannot be seen at all when the light falls perpendicularly upon them, or, at the most, appear then merely as shining points, picture themselves by their shadows in startling silhouettes when illuminated laterally by the rising sun.

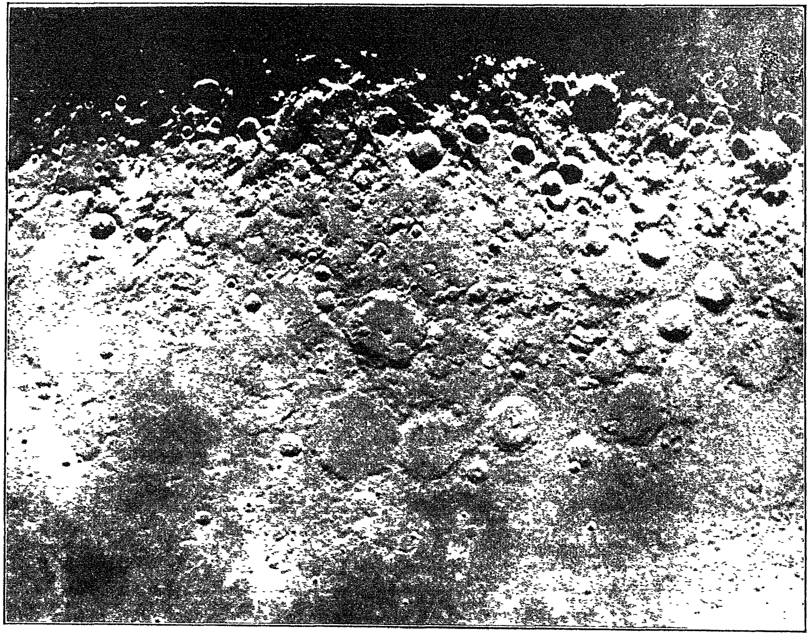
But at full moon, when the mountains hide themselves in light, the old sea-beds are seen spread out among the shining tablelands with great distinctness. Even the naked eye readily detects these as ill-defined, dark patches on the face of the moon, and to their presence are due the popular notions that have prevailed in all quarters of the globe about the "Man in the Moon," the "Woman in the Moon," "Jacob in the Moon," the "Hare in the Moon," the "Toad in the Moon," and so on. But, however clearly one may imagine that he discerns a man in the moon while recalling the nursery rhymes about him, an opera-glass instantly puts the specter to flight, and shows the round lunar disk diversified and shaded like a map.

A feature of the full moon's surface that instantly attracts attention is the remarkable brightness of the

southern part of the disk, and the brilliant streaks radiating from a bright point near the lower edge. The same simile almost invariably comes to the lips of every person who sees this phenomenon for the first time — "It looks like a peeled orange." The bright point, which is the great crater-mountain Tycho, looks exactly like the pip of the orange, and the light streaks radiating from it in all directions bear an equally striking resemblance to the streaks that one sees upon an orange after the outer rind has been removed.

The early selenographers certainly must have been men of vivid imagination, and the romantic names they gave to the lunar landscapes, and particularly to the "seas," add a charm of their own to the study of the moon. Who would not wish to see the "Bay of Rainbows," or the "Lake of Dreams," or the "Sea of Tranquillity," if for no other reason than a curiosity to know what could have induced men to give to these regions in the moon such captivating titles? Or who would not desire to visit them if he could? though no doubt we should find them, like the "Delectable Mountains" in the "Pilgrim's Progress," most charming when seen from afar.

Tycho is the most famous of the crater-mountains, though not the largest. It is about fifty-four miles across and three miles deep. In its center is a peak five or six thousand feet high. Tycho is the radial point of the great light-streaks that cause the southern half of the moon to be likened to a peeled orange. It is a tough problem to account for these streaks. They are best seen at full moon. They cannot be seen at all until the sun



CRATERS ON THE MOON

has risen to a certain elevation above them, but when they once become visible, they dominate everything. They turn aside for neither mountains nor plains, but pass straight on their courses over the ruggedest regions of the moon, retaining their brilliancy undiminished, and pouring back such a flood of reflected light that they completely conceal some of the most stupendous mountain masses across which they lie. They clearly consist of different material from that of which the most of the moon's surface is composed — a material possessing a higher reflecting power. Tycho itself, the center or hub, from which these streaks radiate like spokes, is very brilliant in the full moon. But immediately around Tycho there is a dark rim some twenty-five miles broad. Beyond this rim the surface becomes bright, and the bright region extends about ninety miles farther. Out of it spring the great rays or streaks, which vary from ten to twenty miles in width, and many of which are several hundred miles long — one extending across the Sea of Serenity, being upward of two thousand miles in length. It has been truly said that we have nothing like these streaks upon the earth, and so there is no analogy to go by in trying to determine their nature. It has been suggested that if the moon had been split or shattered from within by some tremendous force, and molten matter from the interior had been thrust up into the cracks thus formed, and had cooled there into broad seams of rock, possessing a higher reflective power than the surrounding surface of the moon, then the appearances presented would not be unlike what we actually see.

It was but natural, after men had seen the surface of the moon diversified with hills and valleys like another earth, that the opinion should find ready acceptance that beings not unlike ourselves might dwell upon it. Nothing could possibly have been more interesting than the realization of such a fancy by the actual discovery of the lunar inhabitants, or at least of unmistakable evidence of their existence. The moon is so near the earth, as astronomical distances go, and the earth and the moon are so intimately connected in the companionship of their yearly journey around the sun, and their greater journey together with the sun and all his family, through the realms of space, that we should have looked upon the lunar inhabitants, if any had existed, as our neighbors over the way — dwelling, to be sure, upon a somewhat more restricted domain than ours, vassals of the earth in one sense, yet upon the whole very respectable and interesting people, with whom one would be glad to have a closer acquaintance. But, alas! as the powers of the telescope increased, the vision of a moon crowded with life faded, until at last the cold fact struck home that the moon is, in all probability, a frozen and dried-up globe, a mere planetary skeleton, which could no more support life than the Humboldt glacier could grow roses. And yet this opinion may go too far. There is reason for thinking that the moon is not absolutely airless, and, while it has no visible bodies of water, its soil may, after all, not be entirely arid. There are observations which hint at visible changes in certain spots that could possibly be caused by vegetation, and there are other observations

which suggest the display of electric luminosity in a rarefied atmosphere covering the moon. To declare that no possible form of life can exist under the conditions prevailing upon the lunar surface would be saying too much, for human intelligence cannot set bounds to creative power. Yet, within the limits of life, such as we know them, it is probably safe to assert that the moon is a dead and deserted world. In other words, if a race of beings resembling ourselves, or resembling any of our contemporaries in terrestrial life, ever existed upon the moon, they must long since have perished. That such beings may have existed, is possible, particularly if it be true, as generally believed, that the moon once had a comparatively dense atmosphere and water upon its surface, which have now, in the process of cooling of the lunar globe, been withdrawn into its interior. It certainly does not detract from the interest with which we study the rugged and beautiful scenery of the moon to reflect that if we could visit those ancient sea bottoms, or explore those glittering mountains, we might, perchance, find there some remains or mementos of a race that flourished, and perhaps was all gathered again to its fathers, before man appeared upon the earth.

Mankind has always been a little piqued by the impossibility of seeing the other side of the moon, and all sorts of odd fancies have been indulged in regard to it. Among the most curious is the ancient belief that the souls of the good who die on earth are transported to that side of the moon which is turned away from the earth; while the souls of the wicked sojourn on this side, in full view of the scene of their evil deeds. The visible

side of the moon — with its tremendous craters, its yawning chasms, its frightful contrasts of burning sunshine and Cimmerian darkness, its airless and arid plains and dried-up sea bottoms exposed to the pitiless cold of open space, and heated, if heated at all, by scorching sunbeams as fierce as naked flame — would certainly appear to be in a proper condition to serve as a purgatory. But we have no reason to think that the other side is any better off in these respects. In fact, the glimpses that we get of it around the corners, so to speak, indicate that the whole round globe of the moon is as ragged, barren, and terrible as that portion of it which is turned to our view.

IF WE WERE ON THE MOON

By Sir Robert Stawell Ball

WE must remember that our bodies have been specially organized and adapted to suit our surroundings on this particular world. I do not think it at all probable that a man could exist, even for five minutes, on any other planet or any other body in the universe. We know that within even the limits of our own earth, each one of us has to be provided with a constitution appropriate to a particular climate. An Eskimo is suitably placed in the Arctic regions, a negro on the equator; and were they to change places, it is hard to say whether the heat would not have killed the Eskimo even before the cold killed the negro. But such an attempt at acclimatization would be easy when compared with that which would be required before an inhabitant adapted to one globe could accommodate himself to a residence on another. Indeed, there seem to be innumerable difficulties in supposing that there can be any residence for man, or for any beings nearly resembling man, elsewhere than on his own earth.

Let us specially review a few of the other globes, beginning with the sun. I think we need not give many reasons to show that a man could not live there long. Every boy knows how a burning glass can kindle a piece of paper by concentrating the sun's rays. Some great burning glasses have been constructed with which iron,

steel, and even flints have been actually melted by the sun's heat. It can be proved that the sun himself must be hotter than any temperature that can be produced in the focus of the most powerful burning glass. We certainly cannot conceive any organized being that would find a congenial residence in a temperature vastly hotter than that of the most powerful furnace that has ever been known. Assuredly there can be no life on the sun.

The next celestial world in importance to the sun is, of course, the moon. Could we find here an eligible abode for mankind? The moon would, no doubt, provide the necessary alternation from day to night, but the day on the moon would last for a fortnight, and then there would be black night for another fortnight. During the long day the moon would be terribly scorched, a circumstance which would be hardly compensated for by the fact that even if we survived the scorching we should certainly be frozen to death during the ensuing night. But there would be other insuperable difficulties attending an attempt to make an abode on the moon. The absence of water is one of them, while a still more immediate trouble would arise from the deficiency, if not total absence, of air suitable for respiration. Indeed, it is almost impossible for us to conceive what an airless world would be like. Fishes out of water would not be more uncomfortable than we should find ourselves. But suppose that we managed to bring a supply of oxygen that might enable us to avoid suffocation by the use of artificial respiration, we should still find the moon a very strange world. We could hear nothing,

for sound exists not except in air. We could strike no match and light no fire. We could feel no wind and see no clouds. There would be also an embarrassment of a different kind which I do not see any way of obviating.

Suppose that we were actually on the moon, and that we had in some way obtained the necessary provision of both air and water, and had begun to walk about, we should experience sensations of a novel description. The extraordinary lightness of everything would be specially noticeable. Take a lump of iron which weighs six pounds on the earth, you would find on the moon that it seemed to weigh only as much as one pound would do on the earth. Everybody knows that it requires considerable exertion to lift a fifty-six-pound weight here, but on the moon it would hardly require as much effort as you ordinarily have to put forth to lift ten pounds. Indeed, the weight of every object on the moon would be reduced to the sixth part of that which the same object has on the earth. No doubt in some ways that might prove a convenience to the moon dwellers. Their bodies would partake of the general buoyancy; walking and running would be amazingly facilitated; and the same effort that would enable you to jump over an obstacle three feet high here would carry you with ease over a wall eighteen feet high on the moon. A good cricketer can throw a ball about a hundred yards here. If he made the same exertion on the moon he could throw the ball over a third of a mile. The diminished gravitation would prove of service in athletic performances on the moon. Not only would a bicycle be driven along with unparalleled ease and rapidity if the lunar

roads were smooth, but even the disagreeable process of taking a header over the handles would lose its terrors, for the lunar bicyclist would fall gently and softly to his mother earth. It may, however, be questioned whether our bodies would be adapted for a life under such conditions. It seems almost certain that as the muscular system of the human body has been arranged to work with the particular gravitation that is found on this earth, it would be impossible for it to be accommodated to a gravitation which had only a sixth of the intensity for which it was adapted. On these grounds we conclude that neither the times nor the seasons, neither the gravitation nor the other distinctive features of the moon, would permit it to be an endurable abode for life of the types we are acquainted with.

HOW WE KNOW THE CORRECT TIME

(Abridged)

By C. H. Claudy

ON the outskirts of the city of Washington, D. C., in a beautiful park, are several white stone and white sheet-iron buildings, all of curious forms, and with odd windows and still odder domes upon them. Inside these various buildings and domes and behind these windows are many astronomical instruments, from the hand sextant to the mighty twenty-six-inch refractor, and busied about them, a corps of expert astronomers and mathematicians.

The world at large knows little of the institution, save that it exists. That it is at the bottom of the regularity of the lives of eighty million people, is a concept almost revolutionary, but as time controls the world, and time, as regards watches and clocks and high noon and midnight, is here determined from the heavenly bodies which make its steady, implacable and never-varying march a possibility, the importance of the institution is greater, astronomically considered, than that within the other white stone and lofty-domed building, wherein sit five hundred lawmakers. They govern the country, but time governs them!

If you ask one of these lawmakers, or even a member of the staff of the Naval Observatory, what is the most

important work of the naval institution, he will answer, "The American Ephemeris and Nautical Almanac," and, if pressed for an explanation, will tell you that the Naval Observatory was founded for the purpose of preparing this volume from year to year and doing the necessary work of ascertaining stellar position to keep it up to date and accurate, for the benefit of the United States navy in particular and all shipping in general. And, to the Government, this is the one and only purpose of the institution. But to perform this work, time must be determined, and as this time determination affects the whole country, while the Nautical Almanac affects the navy and merchant marine only, it is not hard to see why the daily time signals are really the vital part of the Observatory's work to the world at large.

And, like most important things, this matter of time determination is a simple thing, in its theory and elements at least.

Noon at any place is that moment when the sun is directly over a north and south line passing through that place. A day of twenty-four hours is the interval between two "transits" or crossings of the sun over any one meridian. That is the theory. But as the sun has an apparent motion of its own — really our own movement about it in a year — the time from transit to transit of the sun and from transit to transit of a star differs, the amount being about four minutes longer in this sun-measured day than for the one measured with the stars. Moreover, the sun's apparent motion is not uniform, so that some days, measured by the sun, would be longer

than others, and have minutes and hours of different lengths from others. Obviously, this would n't do.

We consider that point in the heavens called the vernal equinox, and take its transit across the meridian as the noon of the sidereal day, but as it occurs anywhere in the twenty-four hours some time in the year, it won't do for trains and people and meals.

So a "fictitious sun" is imagined, which has the same yearly apparent movement as the real sun, but its movement is even and regulated — which, being imaginary, is not difficult of accomplishment — and it is by this fictitious sun that our own system of commercial everyday time is governed. Having gone so far, we went a little farther and divided our country into five zones, called time zones, and made our fictitious sun jump from the center of each zone to the center of the zone next it, and take these jumps one hour apart. If it were not for this, we might have to set our watches every time we took a trolley ride; every town and hamlet would have its own individual noon, differing from every other individual noon, according to its difference in longitude with the standard meridian at Washington or at Greenwich, England. Confusion in time-tables, not to say business, would surely result. As it is, we have Colonial time, Eastern time, Central time, Mountain time, and Pacific time, each differing from the other exactly one hour, and the noon in each the fictitious noon of our fictitious sun. The real noon, or time of the sun's transit, and the fictitious noon, however, are never more than thirty minutes apart, so noon for any place is practically when the sun is on the meridian.

Of course the finest of clocks are used at the Observatory to keep the time. The standard clock is in a vault, underground, where the temperature never changes. It is in a glass case, where the atmospheric pressure is always kept slightly below that of the lowest possible barometer reading, for changes even in the surrounding air-pressure make a difference in the running of the clock. The standard clock is wound every half minute by electricity, using a very small weight, because heavy weights and long intervals between windings cause fluctuations in the way the clock runs. The mechanism is as simple as that of a clock can be, and is as fine as the finest of material and the finest of workmen can make it.

But, in spite of all that, the clock does *not* keep perfect time. No clock or watch in the world keeps true time. The only thing in all the world that does keep time is the earth itself and its changeless rotation.

So the clock is constantly compared with the true time derived from star or sun. An instrument called a transit, or, in the case of the Observatory, a meridian circle, is used for this work, and for the reason that the work it does is so indispensable, it is really this simple instrument which is the most important in the whole institution, and not the mighty twenty-six-inch refractor, impressive and picturesque as it is. This meridian circle instrument is a telescope of moderate size and power, mounted on bearings or trunnions, which point to the true east and west. The telescope, therefore, points always at the north and south.

Now, observations for a hundred and fifty years have

provided astronomers with many tables and much data. We know to a hair just the exact instant when a certain star — any one of hundreds of stars — will cross a certain meridian of any given place. So, if at the instant that it does cross a certain meridian, we note the time the clock gives for that meridian, we know the error of the clock. This error, or rate, as it is called, is fairly constant. While we can't make clocks that keep time with the stars, they do, pretty well, keep time with themselves and lose or gain an equal amount day after day. But this rate does vary a little, and it is this little variation which the observation on the star corrects.

Of course, in determining the rate of the standard clock, observations are made every day, on the sun, when it is visible, and every night, not on one but a dozen stars, and the mean is taken of the observations, to reduce errors of the "personal equation of the observer."

This is a curious thing. A man at the eye end of a telescope sees a star move across the field of view and pass a cross-hair in that field. At that instant he presses a telegraph key. The star goes on and passes over another hair, and again he pats the key. Thus for several hairs. Every pat of the key makes a chronograph — an instrument which records time in an inky dotted line on a revolving drum — record the pat or time of transit. But, in spite of training and practice, the man does n't "get" the star just as it touches the hair. He gets it too soon or too late; he is "slow" or "anticipatory" in his personal equation. But he, like a fine clock, is fairly constant in his personal equation, which is known by many tests and allowed for. And each of many observ-

ers makes many observations, and from them all the mean is taken for a true determination of the error of the clock.

Well! We have now seen how the clock, in its dark vault underground at Washington, gets its time from the stars. But how do you and I, and the trains, and men, women and children, get the time of the clock?

Electrically corrected by this standard clock are two time-sending clocks, in the main building of the Observatory. There are two, so that if one breaks down, time-signals will still be sent out. Every day, just before noon, Eastern time, the trunk lines of the Postal and the Western Union Telegraph systems are cleared of all other business, and the sounders in the main offices of the country begin to beat out seconds. At the end of every minute of the five minutes before twelve there is a short wait of five seconds. And just before noon, for ten seconds, the sounders all stop beating seconds. And then, just on the stroke of noon, they all begin to chatter hard, a long roll. Noon is here.

Then, of course, the fine clocks in the main offices of all the telegraph companies are electrically regulated by the same signal, and they, in their turn, electrically regulate jewelers' and hotel clocks through the cities, and you and I stop and get our time from the jeweler's window and his electrically regulated clock, and we set the kitchen clock from our watches, and so, through a devious course, the little star which passed the cross-hair in the meridian circle instrument has regulated the time at which we shall eat an eight-o'clock breakfast to-morrow morning!

But the timework of the Observatory does not stop with the determination of noon at Washington and the sending out the signal all over the country. It should be noted that the difference between the real noon at one place and at another is an accurate measure of the difference in longitude of the two places. It is to this fact that the seaman owes his ability to find out where he is at any time, even though there are no telegraphs or landmarks on the pathless water to tell him.

If he can find out the exact moment which is *his* noon, and can compare that noon with the noon of some known place, the difference in time, after corrections necessary through errors of refraction, elevation, clock rate, etc., have been made, will show the difference in miles between his location and the basic location.

So every ship carries one or more chronometers and a sextant. With the sextant, the captain of a ship can find the local time by observing the sun, preferably three or four hours before or after noon. The chronometer shows the hour of the place where it was set, and the difference, after corrections, is easily translated into degrees and miles.

Every battleship in our navy carries at least four chronometers. Three of these are for the registry of the time at Washington, and one, a "hack," or traveling chronometer, to be carried about the ship as may be needful.

And why three? So that if one goes wrong, it may be known. If there were but one chronometer, it might go crazy, and the captain never know it. If there were two, one might go wrong and he would be unable to tell which

was slowing up or running ahead. But, having three, if one goes wrong, the other two, agreeing, will show the culprit!

The adjustment and rating of these chronometers is of vital importance. No one expects a chronometer to keep accurate time, any more than the much finer and more delicate astronomical clock. But they are expected to run at a constant rate, that is, to lose or gain a constant amount daily. If this rate is known, and does not change materially, the exact noon at the Washington or Greenwich meridian can always be determined. So there are always dozens, sometimes hundreds, of chronometers ticking away in special cases at the Observatory, each being constantly observed and corrected and rated and logged and written about, until, when some battleship goes into commission for a cruise, she takes with her a set of chronometers which having run with regularity and a constant and known rate for some time in the past, can be reasonably depended upon to run with the same regular loss or gain in the future.

Of course, the determination of noon on the battleship is but a part of navigation. It is necessary to know latitude as well as longitude, and to be able to tell time from moon or stars as well as sun. To accomplish this, it is required that an almanac, or, as it is called here, an Ephemeris, be published every year, possessing the necessary tables and information regarding the stars, their time of transit across the meridian, the moon and its motions, the sun and its position, and the long, long tables of logarithms and numbers necessary for the quick determination of latitude and longitude at sea,

from the use of sextant, star, sun or moon observation, and the chronometer.

Nor must the importance of the absolute accuracy of this Ephemeris be underestimated. It is not too much to say that the value of a battleship and the safety of every life aboard her may hang upon a decimal point in the tables in this book. If you doubt this, read this little true story, told me by Captain Joshua Slocum, of the Spray, he who sailed around the world alone in his own boat, being the "cook and the captain bold and the mate of the (in this case) good ship Spray," all by himself.

"I was right in the middle of nowhere in particular," said the Captain, "and was working out an observation. I did it every clear day for three years, and got safely into ports I was working for, so it is to be supposed I knew how. Well, when I worked out this position, I was seventy miles from where I ought to have been, and that without any wind or gale or storm or anything to account for it. I knew I had n't drifted any seventy miles out of my course in the last twenty-four hours, and I knew I was n't crazy. So, either my work was wrong, my observation faulty, or the tables from which I worked were wrong. I did n't believe any of them were. But I went over them all. And it *was* the table from which I worked. There was a misplaced decimal point — it was a fly-speck! Of course, I had to light on that particular table and that particular set of figures in a book containing millions of them; you can figure on the chances of a man being on that one spot on that one day, and making an observation at that particular hour

which would make the use of that particular set of figures necessary! But I was glad my work was n't wrong."

Now, suppose that fly-speck had been a real error? Suppose the Spray had been a battleship? And suppose those seventy miles had meant the difference between deep water and plenty of sea room, and a rock-bound coast in a storm? It would n't do to have $3,000,000 and three hundred lives hanging on decimal points that way, if those decimal points were in the habit of going wrong. Hence it is that Congress maintains this institution, and it is for this reason that expensive instruments, the brainiest of astronomers and the most careful proof-reading and computations in the world go to the making up of this volume, on which all navigation centering about the United States depends.

SHOOTING STARS

By Elizabeth G. Chapin

MOST young people like fireworks, and it is safe to say that if our modern safe-and-sane Fourth of July celebration did not admit of some display of rockets, Roman candles, etc., the youth of this nation would find Independence Day a hollow mockery. Does it ever occur to you that the sky can give you a dazzling, heavenly sort of firework these August nights, far more fascinating — when you have your eyes and mind open — than any human combination of powder and paper? "Shooting stars," so-called, are dashing their way across the heavens in almost countless numbers nightly (Professor Newcomb estimates them at 146,000,000,000 annually), and many of you no doubt have seen an occasional one when it strays into this earth's atmosphere, only to be snuffed out in a flash, after ages of traveling in space. They come in great numbers at certain fixed periods; and on clear August nights, particularly around August 10, we may hope to see a display. You will watch these shooting stars with much greater interest if they mean to you something more than a streak of light, quickly erased from the blackboard of the sky.

Only within recent years have scientists agreed on the present theory of the nature and habits of shooting stars, or meteors as they are more technically called, but the history of their appearance goes away back to ancient

times, before 1000 A.D., and many superstitious but poetic and romantic ideas have clung about them. A Moslem tradition tells us that evil spirits used to climb up to Paradise to overhear the angels, who drove their prying foes from the heavenly regions by hurling fiery arrows, seen by mortals as shooting stars. The Moslems believed that every such arrow hit its mark, and that its passage across the sky was visible evidence of the extinction of a bad spirit. Another and much sweeter tradition is the old French folklore belief that every shooting star meant a soul entering Paradise. The poet Béranger put this into verse.

One of the very early accounts of a notable display of meteors is associated with the death of the Moorish king, Ibrahim Ben Ahmed, October, 902 A.D., when the chronicler declares that "falling stars scattered themselves across the heavens like rain." The people were terribly frightened and took the display as an evil omen. To modern minds the interesting point of this chronicle is that it fixes the date of the display; many years later this date became a useful point of comparison in showing that similar wonderful displays have been observed at fairly regular intervals of thirty-three years, in later times always in November. In 1698 a meteoric shower was widely observed, and since that date the displays of Leonids — as the November 13 showers are called — have occurred with noticeable regularity. Humboldt and Bonpland made observations in South America in 1799. In 1833 and in 1866 November again saw showers which attracted wide attention among scientists, as well as popular interest amounting in some instances to ter-

ror. A South Carolinian eye-witness of the 1833 shower tells how the negroes on his plantation fell to the ground, praying for mercy, and believing that the end of the world had come. This Leonid shower was seen from the West Indies to British America, and from sixty to one hundred degrees west longitude from Greenwich. A sea captain just bringing his good ship Restitution into harbor at Salem, Mass., testified that he watched the fall of meteors from midnight to daylight. The phenomenon of the 1866 visitation has been brilliantly discussed in Sir Robert Ball's "Story of the Heavens"; in 1899 great hopes were entertained of another equally wonderful illumination, but though a meteoric shower occurred, it was not notable. Now we shall have to wait till about 1933 to see the Leonids again in their glory.

There is a reason why these showers come at intervals, why the Leonids are seen only every thirty-three years or so, while the Perseids are on view each August. To understand their appearance we must know something of their nature and habits. Meteors are now thought to be tiny bits of matter, many of them about the size of a cherry or even a cherry pit, which have been traveling for ages in space, but traveling in well marked paths or orbits (these being in the shape of a long ellipse), around the sun. At certain fixed points in space their orbits intersect with the earth's orbit. Now the earth has a sort of envelope or shield of atmosphere from seventy-five to one hundred miles thick from the earth's crust outward. When the earth's path crosses the path of any group of these meteors, which are said to travel in swarms, some of the meteors will collide with our ring of atmos-

phere, which resists them. The meteor, which has been traveling from ten to forty-five miles a second through unresisting space, is carried by its own velocity against our atmosphere with terrific force. You all know that when you wave a fan gently against the air, you feel almost no pressure, yet when you wave it hard and fast, the fan has to push the air like something solid. So the meteor, pushing hard because of its great speed, encouners resistance, compresses the air which it hurls in front of itself, becomes heated with its own effort encountering the effort or resistance of the air, to the point of incandescence. This rapid motion through the air tears off particles of heated incandescent matter which are left behind to form the tail or trail of the meteor. The meteor, we must remember, is not visible until it enters our atmosphere where it burns itself out in a few seconds.

Now, while vast numbers of these meteors are yearly colliding with our air and being snuffed out, they are not dropping haphazard, but hit us when our earth reaches certain fixed positions on its orbit, and always seem to drop from a given point called their radiant. In August, when the constellation of Perseus is in the ascendant, they appear to drop from the vicinity of that constellation, and take the name of Perseids. They move in an endless chain or belt, much denser at some points than at others. The earth's path happens to cross the Perseids' path just when its — the Perseids' — path is most crowded with meteors traveling in their swarm. Thus naturally more Perseids will collide with Earth's atmosphere and become visible than if a thinly populated

section of their belt rushed past us in August. The same condition is true of the Leonids which travel near us when Leo is in the ascendant, but it so happens, as has been said, that this approach occurs only once in thirty-three years, about November 12 or 13, at which time the shower has been conspicuously brilliant.

A FALLING STAR

By Sir Robert Stawell Ball

COULD an ordinary shooting star tell us its actual history, the narrative would run somewhat as follows: —

"I was a small bit of material, chiefly, if not entirely, composed of substances which are formed from the same chemical elements as those you find on the earth. Not improbably I may have had some iron in my constitution, and also sodium and carbon, to mention only a few of the most familiar elements. I weighed only an ounce or two, perhaps more, perhaps less — but you could probably have held me in your closed hand, or put me into your waistcoat pocket. You would have described me as a sort of small stone, yet I think you would have added that I was very unlike the ordinary stones with which you were familiar. I have led a life of the most extraordinary activity; I have never known what it was to stay still; I have been ever on the move. Through the solitudes of space I have dashed along with a speed which you can hardly conceive. Compare my ordinary motion with your most rapid railway trains, place me in London beside the Scotch express to race to Edinburgh; my journey will be done ere the best locomotive ever built could have drawn the train out of the station. Pit me against your rifle bullets, against the shots from your

hundred-ton guns; before the missile from the mightiest piece of ordnance ever fired shall have gone ten yards I have gone a thousand yards. I do not assert that my speed has been invariable — sometimes it has been faster, sometimes it has been slower; but I have generally done my million miles a day at the very least. Such has been my career, not for hours or days, but for years and for centuries, probably for untold ages. And the grand catastrophe in which I vanished has been befitting to a life of such transcendent excitement and activity; I have perished instantly, and in a streak of splendor. In the course of my immemorial wanderings I have occasionally passed near some of the great bodies in the heavens; I have also not improbably in former years hurried by that globe on which you live. On those occasions you never saw me, you never could have seen me, not even if you had used the mightiest telescope that has ever been directed to the heavens. But too close an approach to your globe was at last the occasion of my fall. You must remember that you live on the earth buried beneath a great ocean of air. Viewed from outside space your earth is seen to be a great ball, everywhere swathed with this thick coating of air. Beyond the appreciable limits of the air stretches the open space, and there it is that my prodigious journeys have been performed. Out there we have a freedom to move of which you who live in a dense atmosphere have no conception. Whenever you attempt to produce rapid motion on the earth, the resistance of your air largely detracts from the velocity that would be otherwise attainable. Your quick trains are impeded by air, your artillery ranges are shortened

by it. Movements like mine would be impossible in air like yours.

"And this air it is which has ultimately compassed my destruction. So long as I merely passed near your earth, but kept clear of that deadly net which you have spread, in the shape of your atmosphere, to entrap the shooting stars, all went well with me. I felt the ponderous mass of the earth, and I swerved a little in compliance with its attraction; but my supreme velocity preserved me, and I hurried past unscathed. I had many narrow escapes from capture during the lapse of those countless ages in which I have been wandering through space. But at last I approached once too often to the earth. On this fatal occasion my course led me to graze your globe so closely that I could not get by without traversing the higher parts of the atmosphere. Accordingly a frightful catastrophe immediately occurred. Not to you; it did you no harm; indeed, quite the contrary. My dissolution gave you a pleasing and instructive exhibition. It was then, for the first time, that you were permitted to see me, and you called me a shooting star or a meteor.

"You are quite familiar with the disasters associated with the word collision. Some of the most awful accidents you have ever heard of arose from the collision of two railway trains on land or of two ships in the ocean. You are thus able to realize the frightful consequences of a collision between two heavy bodies. But in the collision which annihilated me I did not impinge against any other heavy body. I only struck the upper and extremely rare layers of your atmosphere. I was, however,

moving with a speed so terrific that the impulse to which I was exposed when I passed from empty space even into thin air was sufficient for my total disruption.

"Had the speed with which I entered your atmosphere been more moderate — had it been, for instance, not greater than that of a rifle bullet, or even only four or five times as vast, this plunge would not have been fatal to me. I could have pierced through with comparative safety, and then have tumbled down in my original form on the ground. Indeed, on rare occasions something of this kind does actually happen. Perhaps it is fortunate for you dwellers on the earth that we shooting stars do generally become dissipated in the upper air. Were it not so, the many thousands of us that would be daily pelting down on your earth would introduce a new source of anxiety into your lives. Fortunately for you, we dart in at a speed of some twenty miles or more a second. Unfortunately for us, we learn that it is the 'pace which kills.'

"When from the freedom of open space I darted into the atmosphere, I rubbed past every particle of air which I touched in my impetuous flight, and in doing so I experienced the usual consequence of friction — I was warmed by the operation. If you rub a button on a board it will become warm. If you rub two pieces of wood together you can warm them, and you could even produce fire if you possessed the cunning skill of some people whom you are accustomed to speak of as savages. Nor need you be surprised to find that I was warmed by merely rubbing against air. If you visit a rifle range and pick up a fragment of a bullet which has just struck the

target, you will find it warm; you will even find it so hot that you will generally drop it. Now whence came this heat? The bullet was certainly cold ere the trigger was pulled. No doubt there is some heat developed by the combustion of the gunpowder, but the bullet cannot be much warmed thereby; it is, indeed, protected from the immediate effect of the heat of the powder by the wad. The bullet is partly warmed by the friction of rubbing against the barrel of the rifle, but doubtless it also receives some heat by the friction of the air and some from the consequence of its percussion against the target. You need not, then, wonder how it is that when I am checked by your atmosphere I, too, am heated.

"Remember that I move a hundred times as swiftly as your rifle bullet, and that the heat developed in the checking of the motion of a body increases enormously when the velocity of the body increases. Your mathematicians can calculate how much. They tell you that the amount of heat potentially contained in a moving body varies as the square of the velocity. To give an illustration of what this means, suppose that two rifles were fired at a target, and that the sizes of the bullets and the ranges were the same, but that the charge in one of the rifles was such that its bullet had twice the initial velocity of the other. Then the mathematician will say that the heat developed during the flight of the rapid bullet might be not alone twice but even four times as great as that developed in the slower bullet. If we could fire two bullets, one of which had three times the speed of the other, then, under similar circumstances, the heat generated ere the two bullets were brought to rest

would be nine times greater for the more rapidly flying bullet than for the other one. Now you can readily comprehend the immense quantity of heat that will have been produced ere friction could deprive me of a speed of twenty miles a second. That heat not merely warmed me, but I rapidly became red-hot, white-hot, then I melted, even though composed of materials of a most refractory kind. Still friction had much more to do, and it actually drove me off into vapor, and I vanished. You, standing on your earth many miles below, never saw me — never could have seen me — until this supreme moment, when, glowing with an instantaneous fervor, I for a brief second became visible. You shouted, 'Oh! there is a shooting star!'

"Nature knows no annihilation, and though I had been driven off into vapor and the trial by fire had scattered and dispersed me, yet in the lofty heights of the atmosphere those vapors cooled and condensed. They did not, they never could again reunite and reproduce my pristine structure. Here and there in wide diffusion I repassed from the vaporous to the solid form, and in this state I wore the appearance of a streak of minute granules distributed all along the highway I had followed. These granules gradually subsided through the air to the earth. On Alpine snows, far removed from the haunts of men and from the contamination of chimneys, minute particles have been gathered, many of which have unquestionably been derived from the scattered remains of shooting stars. Into the sea similar particles are forever falling, and they have been subsequently dredged up from profound depths, having sub-

sided through an ocean of water after sinking through an ocean of air.

"The motes by which a sunbeam through a chink in a closed shutter is rendered visible, are no doubt mainly of organic origin, but they must also frequently comprise the meteoric granules. These motes gradually subside upon the tops of your bookcases or into other congenial retreats to form that dust of which good housekeepers have such a horror. It is certain that the great majority of the particles of which ordinary dust is constituted have purely terrestrial sources which it would be impossible to endow with any romantic interest. It is equally certain that in a loathed dust heap are many atoms which, considering their celestial origin and their transcendent voyages, would have merited a more honored resting place."

ABOUT NEBULÆ AND THE SPECTROSCOPE

By William Bayard Hale

IT must not be supposed that the modern astronomer spends his time sleeping by day and by night peering through the small end of a telescope. Of course, some observers must be always at the business of surveying the heavens directly with the eye, but vastly the greater amount of the modern astronomer's time is spent in studying photographs, measuring them under the microscope, and pursuing long and laborious calculations. The photographic camera is a better observer than man because its sensitive plate stores up light impressions, records shorter rays than does the retina of the eye, and gives a vastly wider as well as a more enduring picture. Paradoxical as it may seem, an astronomer to-day gazes more often through a microscope than a telescope, and spends more of his time in the chemical and physical laboratory than in his observatory.

When he is in the observatory, the astronomer is likely to be engaged in keeping a particular star at the precise intersection of two crossed hairs on the object glass of a telescope. He sits by the side of his instrument under a dome open to the sky, in a temperature sometimes below zero. Immense accuracy being necessary, the telescope, with the camera and spectroscope (which during the day have been kept cool by refrigerating

apparatus), must be protected even from the heat of the observer's body in the cold night air. But his most fruitful work is in the day-time study of the results obtained by night.

People ask, "How was the universe created?"

The fact is the universe was never "created." It is in a process of perpetual creation. It is being made, destroyed, and re-made, all the time. The telescope and the spectroscope bring down to us pictures of parts of it in all stages of growth and decay. The most fascinating problem of modern astronomers is the searching out of that great process; the discovery of the method of the world machine. It is a question not of what happened once ages ago, but of what is all the time happening.

Ever since men began to study the heavens rationally they have felt that they would be well started toward the mystery of the universe if they could get close enough to make out the constitution and structure of those faintly glowing cloudlike formations which we know as nebulæ. Almost as soon as the telescope came into use, it was directed hopefully at these objects. When Lord Rosse's great reflector resolved several of them into stars, remote and thickly crowded, it was hastily assumed that stronger glasses would resolve them all — there were no true "nebulæ."

But the process of resolution did not go very far; evidently the star-clouds were more distant than had been supposed. Then came the invention of a new instrument with an amazing capability of detecting all sorts of facts, about worlds far beyond vision.

Everybody knows that when a ray of sunlight is pass-

ing through a prism, it spreads into a ribbon crossed by bars of color. If the band be examined very closely, it will be found that it is crossed likewise by lines. If the source of light be an incandescent solid, like an electric light filament or the sun, the colors will be continuous and the lines will be thin and dark. If the source of light be a glowing gas, the colors will be *dis*continuous, the dark lines becoming broad and bright. It would be more accurate to say that the rainbow of colors will disappear, the bright tinted lines swallowing up the spectrum. Every gas gives its own particular set of lines. The glowing vapor of sodium shows two bright yellow lines, invariably in the same position in the spectrum; the vapor of strontium, two red and blue lines; of potassium, a line in the extreme red and a line in the extreme violet; of copper, a green line; of zinc, blue and green lines.

The explanation of the whole phenomenon is easy, but it is unnecessary here. The point of importance for us just now is that "spectrum analysis" affords a means of infallibly determining two things; whether a glowing body is solid or gaseous, and what it is composed of. As we shall see, it does even far more than this. The spectroscope has become a rather complicated machine, but its principle is simple enough. Iron, for instance, gives several thousand lines. Great nicety is necessary to avoid confusing some of these with some of another substance; the spectroscope — or rather the spectrograph, for in practice spectra are usually photographed rather than directly observed — is an instrument for accurately classifying the lines in lights from various sources.

The belief that the nebulæ were enormous aggregations of far-distant stars was general when, one night in August, 1864, Sir William Huggins turned a spectroscope upon a nebula — that in Draco. He looked, rubbed his eyes, and looked again. The spectrum consisted of three bright lines. There was no mistake about it. That nebula, at least, was not an aggregation of stars. It was a luminous gas.

Since that day the spectroscopic exploration of the nebulæ has been one of the chief pursuits of astronomers. At the present moment it is known that vast tracts of the sky are occupied with true "clouds" of glowing gas, swarms of atomic matter, highly attenuated, islands of star-dust floating in the void of space. So vast are they that many of them must cover billions of times the space occupied by our solar system — though they are so extremely tenuous that they appear merely as faint spots of haze against the background of the sky. The pictures revealed by the researches of observers within the decade have proven that the sky is almost entirely spread with faint nebulosity; on every side float vast clouds of star-dust.

Yet it must not be assumed that all the nebulæ are true clouds of star-dust and nothing more. Comparatively speaking, few of them are merely that. Most give continuous spectra, like the sun.

What does that mean? It may mean that stars are embedded in the midst of some of the nebulæ; it may mean that some of them are composed not of gas but of meteors; or it may signify that these nebulæ are merely in the same line of sight with solid bodies that appear

NEBULA IN ORION

in their midst but which are really much nearer or farther.

It is now fairly certain that the solid bodies (whether they be stars or clouds of meteors) are inclosed within the gaseous nebulæ. Take the great nebula in Orion; the solid bodies that appear to be in the heart of it are moving through space with the nebula. Enough instances of this kind are known to make it certain that many thousand nebulæ do actually enwrap stellar centers, and astronomy has now become a new science largely through the successful search for nebulous spirals.

Intimately connected with the existence of nebulæ is the phenomenon of the sudden flashing forth of stars. It is a common thing, though it never fails to startle observers. Three centuries ago, Kepler was astonished to see in Cassiopeia a star shine forth in such brilliance that it was soon visible by day. In 1876, a new star appeared in the Swan; in 1892, one in Auriga.

The most remarkable recorded instance of the appearance of a "nova" was that afforded early in 1901, when a brilliant apparition flashed forth in the northern sky. When Americans were celebrating Washington's Birthday that year, a Scotchman named Anderson noticed a star of the third magnitude where the night before none had been visible. Indeed, a photograph taken the night before showed stars down to the twelfth magnitude, but failed to record this. The night following its discovery, the new sun surpassed all other visible stars except Sirius. The night of February 25, it was the brightest object in the sky — all the world was watching it. Then it began to wane. February 27 it had sunk to the second

magnitude. In the mean while it discharged into space prodigious quantities of electrified gas.

In August, 1901, on the 22d and 23d, Max Wolf made some long photographic exposures for the nova and, developing them, found to his surprise wisps of nebulous matter attending the star. A month later, Ritchey's photographs showed what looked like a complete nebula encircling it in spiral-like curves. Two months later, Lick photographs revealed the emanation uncoiling and expanding. Plates made by various observers up to the following February confirmed the conclusion that the event, whatever it was, that had made the new star blaze out, was producing, as its brilliance waned, the appearance, at least, of a spiral nebula. Some sort of catastrophe must have called forth these sudden conflagrations. Here is one of the new problems with which astronomers are wrestling.

Now, the spectroscope has another property, perhaps even more wonderful than those we have already noticed.

Any one who has stood by a railway track as a train approached and rushed past must have noticed that the whistle rises in pitch until the train reaches the observer, and then drops. The pitch of the whistle depends upon the rapidity with which the waves of sound strike the tympanum of the ear — as the train comes on, these waves are crowded up; as it recedes, they lengthen out.

In 1868, there came to Huggins the startling idea that light waves from the stars would act in the same way. They would crowd up if the star were approaching; and thin out if it were receding. Just as the approach and

recession of a locomotive's whistle records itself on the ear, the course on which a star is moving would affect the sensitive plate of the spectroscope; if the star is moving toward us, the lines of its spectrum would be crowded toward the violet end (violet being produced by twice the number of waves that produce red). If the star is going away from us, the lines would fall toward the red end. To-day it is possible to tell from the position of the lines in the spectrum of a heavenly body whether it is approaching or receding, and at what speed.

The advance of spectroscopic study has now given us, with a fair degree of accuracy, the distances of a thousand stars and nebulæ where the other day we knew none. It has given us entirely revised ideas of speed, and, of course, it has betrayed motion where none was expected. It has betrayed other things — many dead suns, for instance. It is, however, to results far grander that the survey of the heavens, at last made possible by the spectroscope, now leads us.

It was long ago suspected that the celestial bodies fell into groups; and there was noticed what appeared to be flocks of stars, and great drifting masses.

If one were in an immense crowd of people on the earth, it would not be difficult to tell whether the people were moving and in what direction or directions. But it is a different matter when we are carried through space, without anything solid and unmoving beneath our feet, in the midst of millions of bodies whose movements are relatively exceedingly slow. Still it is possible, by the aid of the data which celestial explorers have now accumulated and through the exercise of great patience and

accuracy, to make out the comparative directions in which we and the stars we see above us are moving. That possibility has been acted upon.

It is a noble thing that man, denizen of a tiny planet revolving in attendance on an inferior sun, dares even to believe that he can go forth in conquering imagination till he stands in the midst of the whirling universe and surveys, comprehending, the amazing procession of worlds that fill the heavens with glory.

CELESTIAL PHOTOGRAPHY

(*Abridged*)

By Huber William Hurt

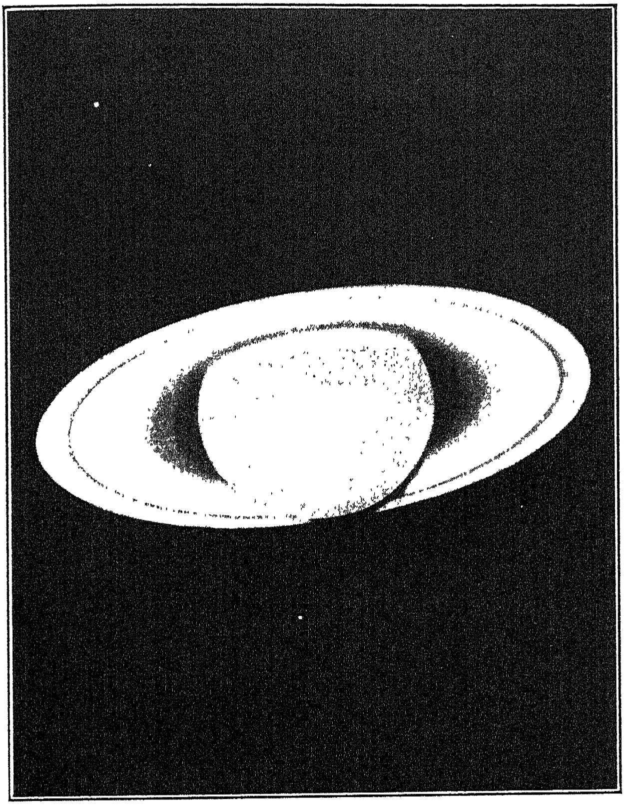
IN the first place, long "time exposures" are necessary because of the great distance of the objects. Naturally, distance limits the quantity of light we receive from a star. Twenty-five minutes suffice for the sun's rays to pass Neptune and go beyond our system, while the nearest star would not be reached by these rays short of several years. How much light can our earth receive from a really distant star — one from which light reaches us only after a thousand or more years of travel? Certainly not enough to make a "snapshot." Light coming from such a source requires an exposure, not of fractional parts of a second, but of several hours.

The moment this time element enters, there arises a second great problem, that of *motion*. Neither the earth nor anything at which we can point our celestial camera can be induced to "sit still." Everything is on the move. The earth itself, on which our instrument must stand, is spinning on its axis practically a thousand miles an hour at the equator. Let us take any point on the earth's surface — the city of Washington, for example — and in thought try to trace its path through space. The earth's daily rotation, considered alone, would cause our capital to travel about eight million miles

yearly. But the earth has also a second motion, which whirls it 18.5 miles each second in its annual journey around the sun. This motion of itself would hurry our city 584,337,000 miles through the emptiness of space in a year. Meanwhile the sun is plunging some twelve to thirteen miles a second along its own highway through the universe, dragging with it its great family of circling planets and moons. This movement alone places more than four hundred million miles to our credit yearly. And the real path of our city is a combination of these three movements — a great, double-spiraled spiral. The mere thought makes us dizzy — as do all these glimpses out into the universe; for example, as imagining a peep over the edge of the world down into the awful chasm of silent space.

Contrast this terrific complex of speeds with those involved in taking a "snap-shot" of a farmhouse from the observation coach of the Twentieth Century Limited! Even this relatively simple process calls for adequate sunshine, rapid shutters, perfect lenses, and practically instantaneous exposure. Imagine, then, the enormity of the problems of celestial photography.

They are enormous despite the fact that, in practical work, only the smallest of these colossal motions disturbs, and then only because it is the smallest. The stars are so unthinkably remote that our annual movement around the sun and the general forward movement of our solar systems are practically negligible. These two larger motions operate so that our field of view would be very slowly, and indeed very slightly, altered. But the daily turning of the earth on its axis means that



SATURN

every minute a definite part of our field of view must shift.

An exposure of but a few minutes, or indeed seconds, makes it imperative that the telescope be moved so as to counteract the earth's rotation. Otherwise our star pictures become long lines of light across the plate. So while the earth revolves eastward, the telescope is moved westward by a delicate, accurate "driving clock," and thus keeps pointing at the same object. These driving mechanisms are extra fine, large clock-gears run by heavy weights, and their speed is regulated either by electrically controlled differential gears, or by eccentric governor-balls which may be adjusted by hand.

Our atmosphere is another source of trouble. Every bit of light that enters has to force its way through fifty or sixty miles of hot and cold air layers, dust particles, clouds of moisture that infest the upper and lower air. We can get an idea of this "air blanket" that surrounds us from looking at the planet Jupiter. Although the largest planet in our system, Jupiter is one of the youngest in its development, and hence is probably in a more heated and gaseous condition. This obviously would react on its atmosphere. At any rate, we can see but little of its surface except under unusual conditions, both here and there.

The slender ray of light from a distant star that penetrates the mists of our enveloping atmosphere is bent aside — first here, then there — by the strata of varying density through which it passes. So it seems constantly to be shifting its position. It twinkles and quivers almost like a cinematograph picture. This inconstancy

of the ray makes the picture big and "fuzzy." Even for an object as near as Mars these atmospheric conditions render it impossible to photograph the polar "ice caps" with sharpness, or to see its "canals" with certainty.

So far there has seemed to be but one effective way to fight these difficulties. Not being able to move the mountain, we must move Mahomet. The telescope, or the plate itself, may be shifted by such small amounts as will send the light constantly to the same spot on the plate. This means sitting and "guiding" through a parallel telescope, or an equivalent prismatic device, so as to keep some selected star always at the center of two perpendicular crosswires in the field of view. The resulting nervous and physical strain is almost intolerably severe. Imagine the fatigue of the long four- to six-hour exposures necessary to get results in photographing the Milky Way, with its thousands of suns, most of them larger than our own, but so distant as to be invisible. Only the summation of several hours of these faint rays will show us anything on the sensitized plate.

It is a surprising but quite natural fact, that even on so-called "clear nights" there appear only moments, fractional parts of a second, of perfect seeing. Only then can one peer through the slender rifts in the clouds, out into the boundless universe. It was in such moments that the distinguished astronomer Young saw so clearly, through his spectroscope, the great gaseous tongues of reddened flame that shot out three hundred thousand miles from the sun's surface. And it is in the power of

the telescopic camera to accumulate a repetition of clear moments that one of its great values lies. It can, so to speak, hold them in reserve until their united strength can be recorded in the picture.

Among the finest photographs ever taken of the surface of the sun, were those of Janssen, of Meudon, near Paris. They clearly showed the solar surface as being composed of great granules, closely laid together. The magnificent detail of these pictures was due to his determined patience. He sat, sentinel-like, waiting and watching, until a moment of transparency came; then he fired.

The photographic plate affords leisure for study, and under normal conditions "snap judgment" does not need to be taken, but the facts are gathered and may later be studied out, weighed, and compared. When the observer is physically and nervously exhausted, and is shivering in the darkened, often freezing atmosphere of the telescope dome, conditions are not ideal for passing critical scientific judgment. Later, with mind and body refreshed, it is evident that he can achieve superior results in magnifying and interpreting the negative.

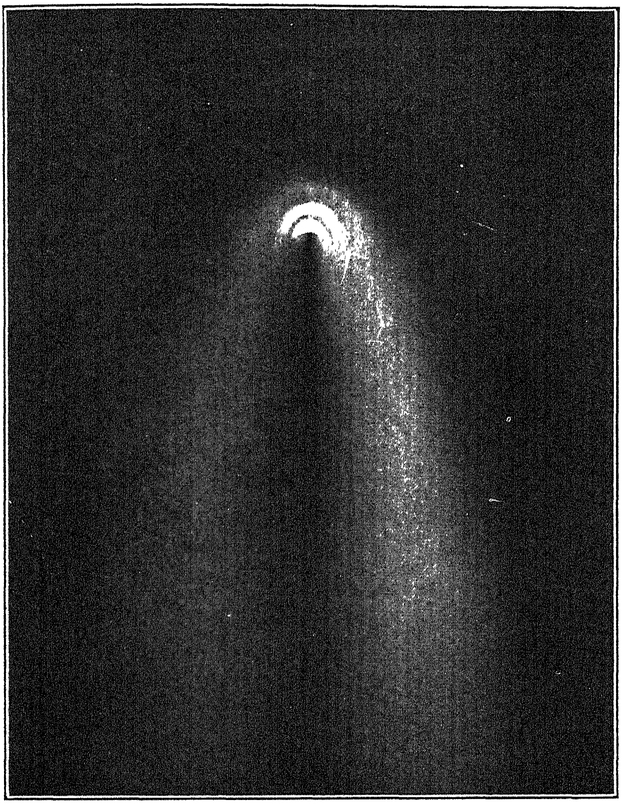
Thus one of the greatest values of celestial as well as terrestrial photography lies in its reliability as a record. It is evidence which scientific and public judgment dare not ignore. No two men ever lived who could look at the same object and then later deliver the same description or judgment of it. Not so with two photographs. Each man interprets his "picture" in terms of his past experiences — the plate records the light that reaches it.

A map of the heavens was with the early astronomers

a prodigious task. It meant sitting at a telescope and observing — hour after hour, night after night, year after year — with pencil and squared paper. Here a big dot, there a small one, to represent the worlds and suns and systems about us. But relief eventually came. The middle of the last century gave us the dry photographic plate. To-day a photograph accurately records at once all of the stars within the reach of the telescope's power and field. Such a chart is to the astronomer what a chart of the ocean is to the mariner. Recently the field has been divided among a number of observatories, and photographs have been taken in different latitudes with uniform instruments. These results have been compiled, and the resulting chart is a marvel of accuracy and reliability.

The great telescopic cameras that have been built in response to a recognition of the value of photography are triumphs of mechanical genius, and it should be no small source of pride to remember that the three greatest equipments of this kind in the world stand on United States soil. They are the Yerkes Observatory of the University of Chicago, at Lake Geneva, Wisconsin — which has the largest refracting telescope in the world; the Solar Observatory of the Carnegie Institute, on Mount Wilson, California, where are the greatest reflecting instruments known; the Lick Observatory of the University of California, on Mount Hamilton, California, whose thirty-six-inch lens is exceeded only by the forty-inch of the Yerkes Observatory.

Though observatories dot the globe in every civilized nation, one fourth of all are located in our own land.



DONATI'S COMET

There is an almost ideal system of intercommunication between the observatories. What one station discovers is placed at the disposal of the others, not only through scientific literature, but very often through immediate, direct means. If at the Cape of Good Hope station a new comet is discovered, this fact and the celestial location of the comet are telegraphed to the world's principal observatories. The next night, scores of inquiring telescopes, like monster cannon, are trained upon the comet, and its every movement is recorded. From this data its path is computed, and we then know whether or not to expect its return to our view. Meanwhile, spectroscopes have been making long-range chemical analyses of the comet's light, and the various elements are identified.

Within the past two decades there has been invented and developed an instrument that can show the distribution of any element on the sun, and can, further, mechanically produce and photograph an artificial eclipse of the sun. This is the spectroheliograph — a huge instrument which weighs eight hundred pounds. In eclipsing the sun, it makes possible the study of the great solar eruptive prominences — those gigantic eruptions of superheated gas from within. The great heat of the sun, estimated at from 10,000° to 40,000° Fahrenheit, naturally turns the various metals and elements into gases, wherever the pressure conditions permit. And the streamers of gas forced forth have been known to shoot out even four hundred thousand miles from the surface, at speeds which have been estimated at five hundred miles a second. Instances are on photographic

record of the failure of this ejected gas to return. It has apparently gone out into the awful stillness of space, growing ever colder and less luminous.

Formerly, to photograph these great solar prominences it was necessary to wait for a total eclipse of the sun, because usually they are obscured by the intense light from the center of the sun's disk. Not infrequently one had to travel to distant, often half-civilized, parts of the earth to see the eclipse. Here the instruments were unpacked, set up, and everything was made ready for the few tense moments of the eclipse, but all under the constant nightmare of the fear of clouds. With the spectroheliograph, simple optical adjustments enable one to eclipse the sun artificially in broad daylight, and *at will* to photograph these gigantic eruptions.

For beauty and fascination there is nothing in the realm of astronomy that equals the spectroscopic view of these eruptions, as seen in the hydrogen light; immense, red, towering, tongue-like clouds of superheated luminous gas. One turns to sketch the shape, and an instant later finds that the shape has entirely changed. But a sensitized plate may replace the eye, and by a series of successive exposures even slow changes are accurately "caught." No fisherman ever reeled in his line with greater anticipation than the observer feels as he rushes to the dark room with the morning's first series of exposures to "see what the sun's doing today."

Scientific studies of light are of intense interest because they contribute so largely to our knowledge of world evolution; how our own earth has developed from

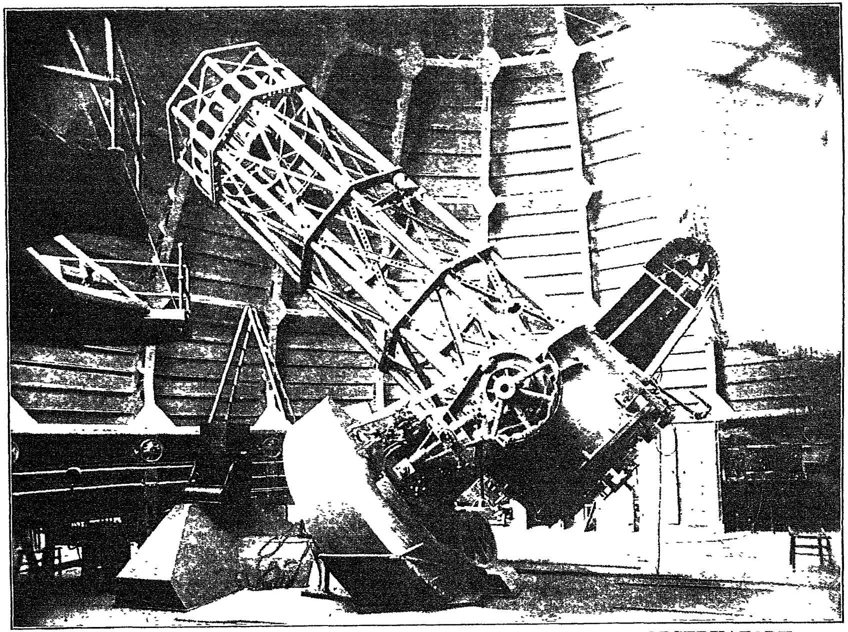
the primitive chaos out of which the stellar systems of our universe have grown in obedience to the divine laws of Nature. This is the vital aim of all purposeful astronomical work — to enable us to understand better the processes of world growth.

THE GREATEST CAMERA IN THE WORLD

By Edward Arthur Fath

THE greatest camera in the world! These words will probably bring to mind some great photographic studio with its skylight overhead, its various backgrounds, its multiplicity of chairs, couches, and similar paraphernalia, and a man with his head under a dark cloth moving a huge instrument about and studying the effects of light and shade while you are trying to "look pleasant." Such a combination, however, is not my theme — the camera of this story is not of the studio type. Instead of being used during the day, it is covered securely as long as the sun is shining; instead of being located in the heart of a busy city, it is placed on the summit of a California mountain; instead of being used to fix the features of the popular actress or the hero of the hour, its operators attempt to fathom with it the depths of the universe and wrest secrets from the stars. This great camera belongs to the Mount Wilson Observatory, located on the summit of a mountain of that name near Pasadena, at an altitude of more than a mile above the waves of the Pacific.

A special road nine miles in length had to be blasted into the flanks of the mountains, and a huge automobile truck of sixty horse-power provided, before it was possible to haul the heavier parts of the great camera to the



THE GREAT TELESCOPE AT THE MOUNT WILSON SOLAR OBSERVATORY
PASADENA, CALIFORNIA

summit. Some of these parts weighed as much as five tons each. When all the parts had been hauled to the site, the huge instrument was set up on a massive pier of reinforced concrete and inclosed in a building of steel which protects it from the heat of the sun as well as from the rain and snow.

This giant among cameras differs in some respects from ordinary instruments of the same name. We are accustomed to think of a camera as having a lens which throws an image of the object to be photographed on a plate, whose dimensions are several times the dimensions of the lens. The instrument under consideration has no lens. It has instead a great mirror five feet in diameter, which has been ground and polished to such a shape that it forms an image precisely as if it were a lens. The photographic plate on which the image falls is relatively small, the average size measuring only four by five inches. The fact that a mirror is used instead of a lens makes some difference in the operation of this camera as compared with the ordinary type, but a consideration of this point would take us too far into the subject of optics to warrant attempting it here.

The accuracy of the reflecting surface of the mirror which is necessary is almost beyond comprehension. The particular curve given to this surface required the services of skilled men for many months before the surface of the great glass was worked to exactly the shape required. The final work had to be done entirely with wax-coated tools and the finest quality of jewelers' rouge. Day after day and month after month were spent in order to obtain the desired result. Toward the end of

the process the work was so delicate that the slight friction between the wax surface of the tool and the glass warmed the latter so that the work could be carried on for but a few minutes at a time. The warming caused a slight distortion of the surface, and it was necessary to wait until it had cooled again before continuing the work. The final outcome was a wonderfully fine surface — so exact that in no place does it differ by more than two one-millionths of an inch from absolute accuracy.

In order to increase the reflecting power of the polished surface an exceedingly thin film of silver is deposited upon it. The reflection is directly from the glass film, the light never entering the glass at all. It has not been found possible to put a transparent protecting coating over the film, which is directly exposed to the air. It therefore tarnishes in time, and must be renewed. This occurs two or three times a year.

But just as the lens is not the whole of the ordinary camera, so the mirror is not all of this one. In order to use this great product of the opticians' skill, it was necessary to mount it carefully. The huge tube — twenty-five feet long — in which the mirror is hung, is made of specially shaped steel, so that it may be both light and rigid. Then, since the stars cross the sky at night just as the sun does during the day, a special driving mechanism had to be constructed so that the instrument would follow the stars. No driving mechanism, however, was ever sufficiently perfect for the work of such an instrument. Constant attention is necessary, for no mechanical device has yet been invented to take the place of the

eye and hand of the skilled observer. The latter must keep the motion so true that at a distance of twenty feet from the driving axis there shall be no deviation from uniformity of motion as great as one one-thousandth of an inch. High power microscopes enable him to detect variations in the action of the driving mechanism, and finely cut screws make it possible to correct for these variations within a fraction of a second after their occurrence.

Another matter which illustrates the accuracy necessary to obtain the best results may be mentioned. As is well known, the ordinary hand camera requires careful focusing in order to yield sharply defined pictures. It is usually necessary to focus correctly to at least one-sixteenth of an inch. The camera which we are considering also requires careful focusing, but to a much higher degree of accuracy. For the finest results the focus is adjusted to the one-thousandth of an inch. Ordinary methods, such as the use of a ground glass, could not be depended upon for such precision, and so a special optical method was devised to meet the requirements.

The exposures necessary to photograph the stars depends upon their brightness. A bright star will make its record on the sensitive plate in a fraction of a second, while a very faint one requires hours. Sometimes even an entire night does not allow sufficient time. The plate must then be carefully covered during the day, and the exposure continued on the next clear night.

In addition to photographing the stars, the great instrument has also been used on those wonderful objects, the nebulæ, the probable birthplace of the stars.

The moon, too, has been photographed, and its mountains and valleys recorded on the sensitive plate. Then there are other uses, such as collecting the light from the stars so that it may be analyzed, and we thus learn of what those distant suns are made.

The value of photographs taken with such care cannot be estimated. In the first place, they often bring to light celestial objects which were before unknown. In the second place, they form permanent records of the face of the sky, which are available for future study. As time goes on the stars gradually change their positions and intensities, and, when present photographs are compared with others taken in years to come, it will be possible gradually to learn the causes of these changes.

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